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Summary of the 2004 herring acoustic surveys in NAFO divisions 4VWX

Résumé des relevés acoustiques du hareng effectués en 2004 dans les divisions 4VWX de l'OPANO

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ABSTRACT

Automated acoustic recording systems deployed on commercial fishing vessels have been used since 1997 to document the distribution and relative abundance of Atlantic herring in NAFO Division 4VWX from industry vessel surveys and fishing excursions. In 2004 regularly scheduled surveys, at approximately 2-week intervals, were conducted on the main spawning components and the spawning stock biomass for each component was estimated by summing these results. Four structured surveys were conducted in Scots Bay, two on Trinity Ledge and three on German Bank following established protocol. This provided good coverage of these spawning areas consistent with previous years. Additional data from fishing nights in Scots Bay and German Bank were examined. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 107,600t, 6,500t, and 367,600t for an estimated total SSB of 481,700t in the traditional survey areas.

Biomass estimates from surveys of the coastal Nova Scotia spawning components for the Little Hope/Port Mouton and Eastern Shore areas were down from those observed in recent years. Various equipment problems precluded estimates being made for the Glace Bay area in 2004. There was again no acoustic survey effort in the Bras d'Or lakes. For the offshore Scotian Shelf there were no large aggregations of herring observed and no acoustic surveys were conducted.

RÉSUMÉ

Des systèmes d'enregistrement acoustiques automatiques installés sur des bateaux de pêche commerciaux sont employés depuis 1997 pour documenter la répartition et l'abondance relative du hareng dans les divisions 4VWX de l'OPANO dans le cadre de relevés de l'industrie et de sorties de pêche. En 2004, on a effectué, à environ deux semaines d'intervalle, des relevés des principales composantes de reproducteurs; on a ensuite évalué la biomasse du stock reproducteur de chaque composante en additionnant les résultats obtenus. Quatre relevés structurés ont été réalisés dans la baie Scots, deux sur la chaussée Trinity et trois sur le banc German, selon le protocole établi. Ces relevés ont assuré une couverture satisfaisante des frayères, comparable à celle des années précédentes. Des données additionnelles recueillies durant des nuits de pêche à dans la baie Scots et sur le banc German ont été examinées. Les estimations de la biomasse pour la baie Scots, la chaussée Trinity et le banc German sont de 107 600, de 6 500 et de 367 600 t environ, pour une BSR totale estimée de 481 700 t dans les zones de relevé habituelles.

Les estimations de la biomasse dérivées des relevés des composantes de reproducteurs des côtes de la Nouvelle-Écosse pour les secteurs de Little Hope/Port Mouton et de la côte est étaient inférieures à celles enregistrées ces dernières années. Divers problèmes d'équipement ne nous ont pas permis d'inclure les estimations de la région de Glace Bay aux résultats de 2004. Encore une fois, aucun relevé acoustique n'a été réalisé dans le lac Bras d'Or. Au large du Plateau néo-écossais, on n'a pas observé de grandes agrégations de harengs, et aucun relevé acoustique n'a été effectué.

INTRODUCTION:

Since 1997 the spawning stock biomass (SSB) of 4WX herring has been estimated using acoustic surveys conducted by the fishing industry (Melvin *et al.*, 1998; Stephenson *et al.*, 1998). Each year commercial fishing vessels equipped with calibrated acoustic logging systems undertake both scheduled and unscheduled surveys of herring aggregations on the spawning grounds. The data collected during these surveys serve two purposes. First, when necessary the data can be analyzed in near real-time, and used as input for the "survey, assess, then fish" protocol, to apportion fishing effort on individual spawning grounds. Secondly, the estimates for individual spawning areas have been summed, under specific assumptions about elapsed time between surveys, to provide an annual index of the SSB for the assessment process. The development and implementation of the automatic acoustic systems represents a major improvement in quantifying fish biomass. Pre-1997 estimates relied on the experience of the observer to estimate the amount of fish from mapping surveys and are considered qualitative only (Melvin *et al.*, 2002b).

The use of commercial fishing vessels to survey and to estimate spawning stock biomass (SSB) was initially developed to provide additional protection of individual spawning components within a global TAC during a period (1994-95) of declining biomass. The original qualitative approach, commonly referred to as the "survey, assess, then fish" protocol, continues today, but now uses a quantitative acoustic methodology with a standard survey design (DFO, 1997; Melvin and Power, 1999; Melvin *et al.*, 2004; Power *et al.*, 2004) to provide an index of spawning biomass.

Several major improvements to our approach have been made in the areas of survey design and in the standardization of survey coverage to a point where they can be considered comparable from year to year (Melvin and Power, 1999; Melvin *et al.*, 2003, 2004; Power *et al.*, 2003, 2004). The most recent improvement, to be discussed in this report, is the introduction of a calibration factor for echo integration.

The purpose of this document is to report and to summarize the 4VWX stock assessment related survey data collected during the 2004 fishing and survey season.

METHODS:

Acoustic and mapping surveys using commercial fishing vessels have been employed to estimate the spawning stock biomass of individual components within the stock complex for the past 6 years. The methods and procedures are well established and described in more detail in previous research documents (Melvin *et al.*, 2000; 2001; 2002a; 2003; 2004).

Data from the 2004 fishing season were obtained during both standard fishing operations and regularly scheduled structured surveys. Structured surveys were either acoustic or mapping surveys (Melvin *et. al.*, 2001). In 2004 no major changes from previous years were made to the established protocol for either acoustic or mapping surveys. The fourteen surveys scheduled for 2004 were completed on or near the tentative dates scheduled and an additional thirteen fishing night surveys were examined in order to enhance coverage. Table 1 summarizes the number of structured surveys undertaken for each area and the locations of these areas are shown in Figure 1.

In general, structured surveys were conducted in accordance with the protocol established in Melvin and Power (1999). In cases of fishing night surveys, there was improvement in the survey design with vessel captains establishing a series of parallel transects to document the fish, rather than the unorganized search pattern common in fishing operations. In addition, the trend of moving away from mapping surveys toward standardized acoustic surveys continued with mapping vessels (without acoustic recording systems) used mainly to enhance the survey coverage area. When structured surveys were undertaken, participating vessels tended to follow standard protocol and there was usually good coverage of the defined spawning survey area. Exceptions to the normal protocols of survey design did take place and these are explained in detail for each situation where this took place.

Length/Weight Relationship:

Prior to 2001, the fish weight variable in the target strength (TS) equation (Table 2) was estimated using a length/weight relationship developed from monthly data for each area. A correction factor of 1.02 was applied to each fish to account for the shrinkage of fish due to freezing, prior to calculating the length/weight relationship (Hunt *et al.*, 1986). This relationship was then used to estimate the weight of a fish for a given length.

The time window used to select data appropriate for individual surveys has changed only slightly in recent years to provide a more representative estimate of mean fish weight. Recent initiatives and continued collaboration with the processing plants, have greatly improved sampling such that it is now possible to obtain a significant number of detailed samples (length/weight data) within a 9-day window (4 days either side each of the surveys). These data are used to develop a weight/length relationship specific to each acoustic survey (Table 2). The mean length of herring sampled during the night of the survey (or from landings of the previous night) and the calculated mean weight is then used to estimate TS specific to each survey period.

Integration Calibration Factor:

In 2003, an option to account for the non-square waveform observed in a ball calibration was incorporated into the HDPS software. This approach is used by several acoustic manufacturers when calibrating their echo sounder. The effect of including an integration calibration factor to estimate backscatter in the integration process varies depending on the vessel's acoustic hardware. The multiplier for the factor typically lies between a positive and negative 0.6 and 1.0, with 1.0 equivalent to an ideal square wave.

Given that the inclusion of the integration calibration factor (ICF) is deemed to provide a more accurate estimate of biomass, it was recommended that all future analyses utilize the ICF to calculate actual biomass (Melvin et al 2004). However, when comparing observations from year to year it was recommended that the comparisons be made between biomass estimates that exclude the adjustment until a time series has been established with the ICF included. After several years only the biomass estimate with the ICF will be needed.

The following analysis presents results using both methods of calculation (with and without the ICF). Comparisons between years are made only with data calculated without the ICF since it has not yet been possible to recalculate the estimates for all years using the ICF.

Acoustic Systems:

In 2004, as in previous years, acoustic data were collected using automated logging systems aboard commercial fishing vessels during both standard fishing excursions and structured surveys. The systems, which were activated whenever the captain wished to document observations, automatically saved all data to the system's hard drive. The data were downloaded at regular intervals to either a removable hard-drive or tape prior to archiving and analysis. Ten automated acoustic logging systems were deployed on commercial fishing vessels in 2004. Systems were installed and calibrated aboard the purse seine vessels *Margaret Elizabeth, Island Pride, Lady Melissa, Dual Venture, Leroy & Barry* and *Secord* and on the inshore gillnet boats, *Bradley K, Hoodster, Jessica & Trevor,* and *Natasha Lee*.

One system was also installed and tested on the herring carrier *Strathaven* based in southwest New Brunswick on Sept. 9, 2004. There are plans to use this system extensively in the 2005 fishing season to conduct surveys near fishing weirs in southwest New Brunswick.

Structured Surveys:

Structured surveys are defined as those surveys that follow the standard protocol described by Melvin and Power (1999). Under this protocol, commercial vessels

follow a series of randomly selected transects within a pre-defined area. The number of transects depends upon the number of vessels involved. Acoustic recording vessels are distributed throughout the survey area to provide representative coverage. The surveys, which are conducted at regularly throughout the spawning season and are generally scheduled at two-week intervals, play an important role in our understanding and perception of the 4WX herring stock. Sufficient flexibility was built into the process to allow for schedule changes, which increased the number of surveys, and allowed for investigation of areas of interest or uncertainty. Structured surveys were conducted on each of the major, and several of the minor, spawning grounds within 4WX, and additional recordings were made of both spawning and non-spawning aggregations during fishing night operations.

Fishing Excursions:

Fishing nights are defined as those occasions when acoustic data are collected by fishing vessels equipped with automated acoustic logging systems during the search phase of a fishing excursion. These data, which do not follow any formal survey design, provide information on the distribution and abundance of herring during non-survey nights. The data have also been used in the past to document large spawning aggregations not included in a survey and/or as a substitute for a survey in the event that no other information is available. The approach to the activation of the systems has changed since the start of the program. During the early stages fishing captains would turn their system on when they reached the fishing ground and off once they deployed their fishing gear. For the last few years, the majority of vessels have activated their systems only when they believed there was something worth recording. This has greatly reduced the amount of time required for archiving, editing and analyzing. Analyses of acoustic data from non-survey nights increased due to the provision of technical support for the program since 2002. Data from fishing nights were examined for Scots Bay and German Bank SSB in 2004. Only one fishing night from the Scots Bay area from July 19, 2004 was used to fill in for missing data not covered by a traditional survey. All other fishing night estimates were found to be lower than the nearest survey estimate for that spawning area and time period and were not used further.

RESULTS:

The spawning biomass for individual components of the 4WX herring stock complex in 2004 was estimated from industry collected data using multiple structured acoustic and mapping surveys on major spawning grounds. These surveys, when summed, provided an index of SSB and formed the foundation for evaluation of the stock status. The following text provides a summary of the 2004 observations and SSB estimates for each of the main spawning components within the stock complex. The number of surveys scheduled, the number actually

completed and the number of fishing nights used in the biomass estimate are summarized for each of the main spawning areas in Table 1.

Bay of Fundy/SWNS Spawning Component:

Biological Sampling for Maturity:

The timing of surveys in relation to the residence time of spawning groups on the spawning grounds continues to be an issue of major concern. The current hypothesis for surveys on individual spawning grounds assumes that there is constant spawning on each ground over the season with individual spawning groups or waves continuously arriving, spawning and then leaving within 10 to 12 days (or less).

Evidence from a tagging experiments conducted in 1998 of ripe and running (spawning) herring showed that the residence time for most returns on the same grounds was less than 7-10 days, however 25% of returns were captured on the same grounds after more than 10 days at large (Paul, 1999). In contrast, a similar experiment in September 2001 on German Bank showed no recaptures after nine days on the same grounds during the same spawning season (Power et al. 2002). This latter result was complicated by a large decrease in fishing effort (and thus returns) during the second week after tagging. Further tagging studies with applications at regular intervals throughout the spawning period have been recommended.

Sampling data for maturity supports the view of continuous spawning with high proportions of ripe and running (spawning/stage 6) fish observed over an extended period (Figure 2, 3). The 10 to 12 day window also assumes that there will be no double counting and that the maturing (hard/stage 5) as well as the spawning (stage 6) fish in the samples will also have spawned and left before the next survey. The proportion of maturing (hard/stage 5) fish appeared to be less on German Bank than in Scots Bay. It is also noteworthy that spent fish are rarely captured even with the intensive daily sampling that is done. This is substantiated by fishermen's reports of the spent fish leaving the spawning grounds very quickly after spawning and rarely being caught.

In 2004, herring maturity data were again obtained from two primary sources: 'Roe Analysis Data Sheets' from Scotia Garden Seafoods processing plant quality control group and from the standard biological sampling program conducted by staff at the St. Andrews Biological Station (SABS). The 'Roe Analysis Sheets' from industry were supplied as available, usually on a daily basis during the spawning period, often with multiple samples from different boats. These are random samples of 50 to 100 fish with the males and females separated and the individual gonads weighed into categories for use by the processing plant. From these data the overall percent weight of mature, immature and spent females as well as

percent weight of the male gonads were determined. The plant classification system must not be confused with the standardized ICES scientific scale of 1 to 8 (Parrish & Saville, 1965) but the roe data can be compared with SABS data based on knowledge of the two comparative methods (Table 3).

The SABS biological samples provide data on individual fish for length, weight, sex, maturity stage, gonad weight and age. For comparison with the industry categorization, data by maturity stages were grouped such that stages 1-3 were called 'immature', stages 4 and 5 (mature/hard roe) were combined as 'maturing', stage 6 (ripe and running) were designated as 'spawning' and stages 7 (spent) and 8 (recovering) were combined as 'spent'. A modification to the SABS lab procedure to weigh all gonad stages was implemented in 2003 in order to make more exact comparison with industry maturity samples which are based on gonad weight. SABS samples were combined for female fish by day and percent numbers and percent weight by the categories determined.

'Roe Analysis Sheets' from 25 Scots Bay samples were provided by Scotia Garden Seafoods from Aug. 3 to Sept. 16, 2004, while SABS maturity data were available for 24 samples from July 13 to Sept. 16 (Figure 2). Fish were confirmed to be in mature condition for all samples throughout this period but the proportion of spawning fish (stage 6) was quite variable from day to day ranging from about 10 to 90% with an average of 55%. This is a typical pattern for the Scots Bay area and has been seen in previous years (Melvin et al, 2004, 2003).

Scotia Garden Seafoods also provided 'Roe Analysis Sheets' for 19 German Bank samples over a 24 day period from Sept. 16 to Oct. 10, 2004. SABS maturity data were available from this area for 13 samples from July 2 to Oct. 7 (Figure 3). The samples again confirmed the absence of immature/non-spawning fish with the proportion of spawning fish (stage 6) at about 90% which is typical for the German Bank area during the spawning fishery (Melvin et al, 2004, 2003).

Scots Bay:

The Scots Bay herring purse seine fishery is an important component of the summer fishery with catches since 1987 ranging from 1,000 to 19,000t during the period of early July to late August-early September (Table 4, Figure 4, 5). The 2004 fishery was unusual in several aspects, with the highest recorded catch of 24,388t and the longest season thus far ending on Sept. 16. The distribution of catches was also more widespread extending both north and east of the innermost strata survey area (Figure 4). The record of daily catches showed high daily landings of over 400t per day for most of the 2004 season with a drop off after September 1.

Four structured surveys were conducted during the 2004 spawning season in Scots Bay between Aug. 3 and Sept. 12 (Table 5). The surveys began slightly later than recent years and continued later into September (the first survey was on

July 16 in 2001). In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets during each survey. Fish samples collected indicated that mature spawning herring dominated samples collected on or near the dates of the three surveys (100% stages 5 & 6), while no immature herring were collected from Scots Bay spawning grounds during the survey period. Overall, the Scots Bays surveys generally followed the protocol and provided good coverage of the spawning area. Data from eight fishing nights in Scots Bay were also analyzed, but only one night (July 19) was used in the final overall estimate of SSB (Table 6).

The first survey in Scots Bay was undertaken on the night of Aug. 3, 2004 with eleven vessels including five with acoustic recording systems. The vessels met off Margaretsville at about 9:00pm where boats with recorders completed preliminary search lines. The survey fleet then was positioned with about one nautical mile separation to begin the survey. One survey pass was made from the southwest to the northeast and extended beyond the standard survey block past Cape D'Or. While there were scattered schools noted on the central transects, no large bodies or areas of fish were observed during the survey (Figure 6).

After the survey ended around midnight, fish were found aggregated near the center of the survey area. Fish behaviour was noteworthy with schools breaking up quickly when boats passed through them, as well as fish found towards the top of the water column and even jumping at the surface. This corresponded to what was seen on most of the sounder recordings with fish mid-water to the surface and not along the bottom. All 11 vessels were able to make successful sets with total landings of 1083t. Six samples were collected for length with a mean size of 26.3 cm (Figure 7). The female roe condition from industry sampling was 60% spawning, 30% hard and 10% spent.

The data were downloaded from the five boats with acoustic recorders. Data problems were encountered with the Dual Venture due to a hardware problem and the Leroy & Barry which required a narrow threshold adjustment. The resulting data was divided into two groups including a pre-survey aggregation of 38 km^2 and the main survey area of 430 km^2. The survey estimate using the calibration integration factor with acoustic recorders was 16,900t with a standard error of 46% for the two areas covered (Table 5b).

The second survey in Scots Bay was conducted on the night of Aug. 16, 2004 with sixteen vessels including five with acoustic recording systems (Figure 8). One survey pass was made from the southwest (off Margaretsville) to the northeast as far as Cape D'Or. At this point, the fleet split with half of the boats extending beyond the standard survey block as far as Scots Bay and the other half surveying into Advocate Bay and back around Ile Haute. Fish were found aggregated in the center of the survey area mostly to the south and southeast of Ile Haute in areas where most recent catches had taken place and most vessels were able to make successful sets after the survey. Five samples were collected with a mean size of

26.5 cm (Figure 9). The average female roe condition was 52% spawning, 47% hard and 1% spent (Figure 2). Target strength of 35.03 dB/kg was estimated from the mean length and the weight/length from available samples on the night of the survey (Table 2).

The data was downloaded from the five boats with acoustic recorders. Various data problems were encountered with the systems that appear to be related to hardware conflicts in the newly installed computers. The computer on the *Island Pride* stopped recording after only 30 minutes and the *Secord* computer also stopped midway through the survey. The problems with these acoustic recording systems have now been resolved. The short incomplete transects by *Island Pride* and *Secord* were not considered representative of the survey area and were excluded from the final runs. As a result of the broken transects and partial lines, the initial survey estimate had a high standard error of 97%. The data were reviewed and transects representing a continuation of the same line were combined to give an overall estimated biomass of 63,300t and improved standard error of 44% (Table 5b).

The third survey in Scots Bay occurred on the night of Aug. 29 with 15 of the 19 active purse seine vessels participating including five with acoustic recording systems. The survey began off Margaretsville and the area covered was equivalent to the previous survey, extending well into both Advocate and Scots Bays. Fish were mainly found aggregated inside the 20 fathom contour off Harbourville along the southern transects (Figure 10).

Nine length frequency samples were collected with a mode at 26 cm and a mean of 26.4 cm (Figure 11). The estimated age of these fish, based on historical mean age data, ranges from 3 to 6 years old. The average female roe condition was 63% spawning, 37% hard and 0% spent/immature (Figure 2).

The data were downloaded from the five boats with acoustic recorders. Data problems were encountered with the loss of navigation data on the *Dual Venture* and the unexplained loss of part of one data file. Using the available transects (Figure 10) and an overall mapping area of 640 km^2, the biomass estimate from the acoustic recorders was 27,100t with a standard error of 67 % (Table 5b).

The final structured survey of Scots Bay in 2004 occurred on the night of Sept. 12 with eight purse seine vessels participating including three with acoustic recording systems. The survey began off Margaretsville and extended as far as Cape D'Or with fish found mainly in the center of the survey area (Figure 12). The area covered of about 330 km^2 was less than previous surveys due to fewer boats participating.

Four length frequency samples were collected with a mode at 26.5 cm and a mean of 27.1 cm (Figure 13). The trends in maturity for Scots Bay in September show all

roe as mature but with the lowest proportion of spawning roe occurring on Sept. 13, the day after the survey (Figure 2).

The data were downloaded from two of the three boats with acoustic recorders. No data was recorded on the *Margaret Elizabeth* due to a power cable problem. Data problems were also encountered on the *Dual Venture* with the loss of navigation data and the unexplained loss of part of one data file including the last hour of the survey. In addition there was evidence of a change in sounder range settings which are required to be fixed while surveying with this vessel. Since the *Dual Venture* data were incomplete in distance traveled, analysis was done making the two available acoustic transects of equal length and calculating an adjusted acoustic survey biomass based on these new averaged transects. These calculations used the overall mapping survey area and resulted in final biomass estimates of 6,700t and 5,800t with and without the calibration integration factor respectively. These results had a standard error of 50 to 57% respectively (Table 5).

Acceptance of these results is also dependant on the assumption that the change in sounder settings on *Dual Venture* was likely to a shallower depth range and a higher ping rate which would result in underestimation rather than overestimation of biomass. However, there is no way of determining whether the setting was at the correct calibrated setting either before or after the change. Future surveys must ensure that sounder settings are not changed during the survey on boats which use direct output of the ships sounder to the automated acoustic recording systems.

Fishing night acoustic data from Scots Bay were examined for eight nights where sufficient data for estimation of biomass were collected (Table 6). Biomass estimates from five fishing nights between July 19 and Aug. 18 were analyzed with SSB's ranging from 160t to 8,260t. Except for the survey for July 19, all of these estimates overlapped survey nights in the ten day spawning timing window and were lower in total SSB than the formal surveys.

The July 19 fishing night survey area was relatively small at 6.0 km^2 but had a relatively high density of fish (Figure 14). Biological samples were available from the fishery and from the July research survey for calculation of target strength (Table 2). The biomass estimate for this night was 922t with the CIF and had a standard error of 32%.

In 2004, the Scots Bay SSB estimated from four structured surveys and one fishing night survey using the calibration integration factor was 115,000t (Table 5b). The 2004 SSB estimate of 107,600t without the integration factor can be compared to data calculated in a similar manner for previous years. The SSB follows a continued decline since the high of 2001 and it is close to the 1997-2004 average of 115,700t.

Trinity Ledge:

As in 2003, the surveying of spawning herring in 2004 on Trinity Ledge continued to be less than optimal and it is unlikely that biomass estimates accurately reflect the abundance of fish in this area. Improvements to the survey approach and adherence to the design protocols are required if the data are to reflect trends in abundance. The area covered by the 2004 surveys on Trinity Ledge ranged from 0.7 km^2 to 12.0 km^2 in a potential spawning area of 200 km^2.

The first structured survey of Trinity Ledge was carried out on Aug. 25, 2004 by a single herring gillnet vessel (*Jessica Trevor*). The survey was divided into two general areas with the majority of fish observed in a smaller south-western area. The larger outer area covered was 10.6 km^2 while the smaller area with dense fish was 1.35 km^2 (Figure 15). Using the calculated target strength of -35.53 dB/kg for a multi-panel net sample on Sept. 7 the estimated SSB for this survey was 5,700t with a standard error of only 17% due to the large number of transects completed (Table 7).

The second and third structured acoustic surveys of Trinity Ledge were carried out on Sept. 5 and Sept. 7, 2004 by a single herring gillnet vessel (*Jessica Trevor*). The sounder data was edited to remove bottom as well as surface noise. Results of the survey transects as 3D-ribbon plots are shown in Figure 16. A biological sample of fish was collected using a multi-mesh gillnet with mesh sizes from 1.5 to 3 inches (Figure 17). The fish captured by these nets ranged from 19.5 to 33.0 cm with over 60% of both male and females in spawning condition. The biomass estimate for Trinity Ledge on Sept. 5 was 2,400t, while the subsequent estimate on Sept. 7 was 6,350 t (Table 7). These two nights are considered to be separate estimates of the same group of fish since they are less than 10 days apart. The second night's larger estimate of 6,350t was used in the overall SSB for the area. The overall SSB estimate for Trinity Ledge spawning component in 2004 was 6,500t without and 12,000t with the use of the calibration integration factor (Table 7).

German Bank:

The German Bank herring purse seine fishery is usually the major component of the summer fishery with catches since 1985 ranging from 16,000 to 53,000t during the entire fishery period of early May to late October (Table 8). Catches during the spawning period defined from Aug. 15 to Oct. 31 have been near 20,000t since 1995 but the 2004 catch only amounted to 10,100t for the main strata survey area (Figure 18). Daily catches in 2004 were also reduced compared to previous recent years with a shorter period of sustained activity than is normally seen from mid-August to the end of the quota year (Figure 19).

Three surveys were conducted during the 2004 spawning season on German Bank between Sept. 2 and Sept. 30 (Table 9). The first survey began slightly later

than in 2003 and the last survey took place well before the end of the fishing season on Oct. 15. In addition to the acoustic recordings, visual observations from the sounder were recorded at 5 to 10 minute intervals on deck sheets. Fish samples, while limited in early September, indicated that mature spawning herring dominated samples collected on or near the dates of the three surveys (100% stages 5 & 6). Overall the German Bank surveys were well conducted and provided good spatial coverage of the spawning area but were limited in temporal coverage.

The first survey of German Bank which occurred on Sept. 2, 2004 involved nine purse seiners, three of which were equipped with acoustic recording systems in which sounder and sonar images were stored for later analysis. Good concentrations of fish were recorded in the central part of the survey in the normal 'tow' area and also in the southern part of the main strata area. Overall, the survey had excellent coverage of about 650 km^2 (Figure 20).

The acoustic recorder data were analyzed for the three recording vessels with all six of the available transects used in the results (Figure 21). Fishing took place after the survey and there were 5 samples available from these landings (Figure 22). These herring were between 18.5 and 33cm in total length with a mean of 26.1cm. Based on mean age data from historical samples these fish ranged from 2 to 8 years old with most between the ages of 3 to 5. Using the available transects and an overall mapping area of 650 km^2 the preliminary total acoustic biomass was 113,300t with a standard error of 24% (Table 9). This estimate is based on the target strength calculated from the available samples and uses the calibration integration factor (CIF) as recommended in the most recent assessment.

The second structured survey of German Bank occurred on Sept. 16, 2004 and involved 11 vessels including 4 with recording systems. The vessels started at 43°34' latitude and were positioned randomly for the run south to latitude 43°14'. Boats were regularly spaced 0.75 nautical miles apart for the run back to the north. The total survey mapping area was 550 km^2 while the area of coverage by acoustic vessels alone was 400 km^2 (Figure 23).

The acoustic recorder data were analyzed for the four recording vessels with five of the eight available transects used in the results (Figure 24). One set of transects were repeated by two different boats and as a result the one with the larger total backscatter (Sa) was selected. There were problems with two other transects, one was missing due to an apparent equipment problem and a second line was incomplete and cut across other transects and thus was removed.

Six length frequency samples were collected on Sept. 16-17 with a mean of 27.0 and modes at 25 and 26 cm (Figure 25). Based on mean age data from historical samples for the month of September, these fish ranged from 3 to 6 years in age with most between 3 and 5 years. One sample collected for roe condition by

industry showed 96% female fish in spawning condition (stage 6), 4% with hard roe (stage 5) and a sex ratio with 60% females.

Using the available transects and the acoustic survey area of 400 km^2 the biomass was 167,500t with a standard error of 37% (Table 9). The mapping survey area of 550 km^2 was not used because few fish were encountered by the mapping boats in the survey area to the west and no lines were done by acoustic boats in that area. This estimate is based on the target strength calculated from the available samples and uses the calibration integration factor as recommended in the most recent assessment.

A third survey was conducted on German Bank on Sept. 30, 2004 and involved 8 purse seiners, including four with acoustic recorders. The total survey mapping area was 660 km^2 providing excellent coverage of the spawning area (Figure 26). Five length frequency samples were collected on Sept. 28-29 with a mean of 26.5 cm and mode at 26 cm (Figure 27). Samples collected for roe condition showed 96% female fish in spawning condition (stage 6), 4% with hard roe (stage 5) (Figure 3).

The acoustic recorder data were analyzed for the four recording vessels with all eight of the available transects used in the results (Figure 28). The area of coverage by the acoustic boats alone was 613 km^2 only slightly less than the overall mapping area of 660 km^2, but all transects were not followed as directed. The purpose of the survey design with assigned lines is to get an unbiased estimate of biomass along the assumed 'randomly' assigned line. There was obvious bias in transect S960 which diverted from the assigned line as much as ¾ mile in order to document a large aggregation before returning to the original line. There are several choices possible in the analysis a) the section of the line could be removed entirely where it was off by more than ¼ mile b) the off track section could be treated as a separate school of fish or c) the survey could be post-stratified with lines with and without substantial amounts of fish (Figure 29). The latter method of post-stratification was used and with the integration factor, the biomass estimate for this third German Bank survey was 111,100t with a standard error of 20% (Table 9).

Fishing night acoustic data for German Bank were examined for five nights where sufficient data for estimation of biomass were collected (Table 10). Biomass estimates from five fishing nights between Oct. 3 and Oct. 7 were analyzed with SSB's ranging from 1,670t to 45,530t. None of these estimates were used in the final SSB for German Bank as they overlapped survey nights in the ten day spawning timing window and were lower in total SSB than the formal surveys.

In summary, the overall spawning stock biomass (without the integration factor) for German Bank in 2004 was estimated as 367,600t from three structured surveys (Table 9) extending from Sept. 2 to only Sept. 30. One survey was re-stratified to account for the apparent bias in a transect path but most of the surveys were well

executed with good coverage of the main survey area. The elapsed time between all surveys was greater than the 10-14 day guideline and turnover of spawning fish was assumed to be 100%. One concern was the lack of a structured survey after Oct. 1 when a major portion of the fishing activity took place and for which there were also good indications of spawning fish from intensive sampling for maturity.

Seal Island:

Historically, the spawning areas around Seal Island made a significant contribution to the biomass of the Bay of Fundy/SW Nova stock complex. In recent years the abundance of herring and the documentation of spawning fish in this area have been intermittent.

In 2002, approximately 1,200t of herring were observed during the spawning season. In 2003 data on the distribution and abundance of spawning herring were collected during a single fishing night on Sept. 15, 2003 and it was estimated that the vessel observed 12,150t of herring, a marked increase from previous years. In 2004 there were no surveys or fishing night analyses. It is suggested that some effort should take place in this area in future years in order to document spawning occupation on these grounds.

Browns Bank :

No surveys or fishing night analysis were undertaken for Brown's Bank in 2004.

Spectacle Buoy:

The spring gillnet fishery for roe occurs each year for a short period in June in the vicinity of Spectacle Buoy located just southwest of Yarmouth, N. S. The fishery is dependent upon the availability of fish and to some extent, market conditions, and may or may not occur in any given year. In 2004, no fishery took place and no spawning herring were caught during May and June.

A single survey of the Spectacle Buoy area was undertaken. *Jessica Trevor* surveyed the area on Aug. 22, 2004 but no herring were encountered (Figure 30).

Bay of Fundy/SW Nova Summary:

Since 1997, biomass estimates determined from acoustic surveys have been used to evaluate the status of the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex. During this time the approach for estimating SSB has evolved from a heavy reliance on distribution and abundance estimates from fishing excursions with a 10 day minimum elapsed time, to structured surveys scheduled at two week intervals. In 1999 spawning areas were defined and survey protocols were established to make the estimates more representative of the actual SSB rather than a minimum observed value. This was accomplished by

undertaking a series of surveys that covered most of the spawning area on each of the spawning grounds during the defined spawning season.

In the absence of survey data fishing excursion data may be substituted as appropriate. Regular monitoring of herring gonad development throughout the season from both industry and DFO sampling provided evidence that the fish surveyed were mature spawners and that a turnover of spawning fish had occurred between each survey (and that at least 10 days had elapsed between surveys). The total observed biomass for the complex was obtained by summing the SSB estimate for each spawning ground. Given the changes that have occurred over time the estimated SSB prior to 1999 should not be compared with those reported since that year.

The estimation of biomass from acoustic backscatter relies on the relationship of TS to length measured under a variety of conditions (Foote, 1987). The size and weight of herring from appropriate sample data have been applied but there can still be considerable variance. Studies in controlled conditions in herring weirs (Melvin *et al.*, 2000, 2001) resulted in absolute differences of 7 to 12% between the acoustic estimate and the biomass removed from the weir by seining. Finally the variance in individual survey estimates as provided in the 2004 tables (SE or standard error) ranged from 17 to 67% and depended on both survey design and the actual variance in Sa observed by transect. Thus small differences observed between areas from year to year are likely not significant statistically (Figure 31).

In 2004, the total SSB for the Bay of Fundy/Southwest Nova Scotia spawning complex was estimated to be 481,700t, a slight decrease from the previous year (Table 11, Figure 31). The SSB for Scots Bay was down by about 25% and is of concern, especially in light of the increased effort and landings for this area. German Bank had a slight increase despite only three structured surveys over a limited time period. Estimates of spawning biomass on Trinity Ledge and Seal Island decreased substantially in most part due to lack of survey effort.

Nova Scotia Coastal Spawning Component:

The shallow inshore waters of the bays and inlets along the Atlantic coast of Nova Scotia support a number of herring spawning populations. Several documents describe reports of coastal spawning in 4VWX (Clark et al., 1999; Crawford, 1979). Our direct knowledge of these relatively small coastal populations is limited to a few areas where there are active commercial fisheries for roe on spawning grounds. The traditional bait fishery occurs in the spring and summer of the year. In 2003, commercial roe fisheries were conducted in three areas of the Nova Scotia coastal stock component: Port Mouton/Little Hope, Jeddore/Eastern Shore and Glace Bay. Surveys of the spawning grounds were undertaken using both the mapping and the structured acoustic survey approach, depending upon the area

and the availability of a recording vessel. The results for each spawning area are presented below.

Little Hope:

Adherence to survey protocol for the spawning grounds near Little Hope/Port Mouton improved in 2002, but was variable in 2003 and 2004. In 2004 there was limited coverage from surveys and a lack of biological samples from the fishery.

The first structured mapping and acoustic survey of Little Hope/Port Mouton was carried out on Oct. 2, 2004 by thirteen vessels including two vessels with acoustic recording systems (Figure 32). The total survey mapping area was 140 km^2 with fish recorded in an area of about 16 km^2. The vessels with acoustic recorders concentrated their effort in the areas with dense aggregations of herring. The results for the largest school found south of Little Hope are shown as a 3D-ribbon plot with fish along the various lines or transects (Figure 33). The total biomass for the night of Oct. 2 was 15,600t with a standard error of 19% (Table 12).

A biological sample using a multi-mesh gillnet was not available and so standard target strength was applied for a 28cm herring based on length and weight from a September multi-mesh sample from East of Halifax (Table 2). One sample collected on October 1, 2004 for roe condition showed 18% female fish in spawning condition (stage 6) and 82% with hard roe.

A second survey of the Little Hope area was done by a single vessel with an acoustic recorder on Oct. 13, 2004 with two areas of fish found south-west of Port Mouton (Figure 34). The sounder data was edited to remove bottom as well as surface noise. The biomass estimate for the two areas surveyed near Little Hope on Oct. 13, 2004 was 7,000t with a standard error of 15% (Table 12). Again, a biological sample using a multi-mesh gillnet was not available and so standard target strength was applied for a 28cm herring based on length weight from a September multi-mesh sample from east of Halifax (Table 2).

The final total 2004 SSB estimate (using the ICF) for the Little Hope area based on the mapping and acoustic surveys was 22,500t from the sum of the Oct. 2 and Oct. 13 surveys.

Eastern Shore:

In 2004, acoustic and mapping surveys in the Eastern Shore/Jeddore area were coordinated by the Eastern Shore Fishermen's Protective Association. Surveys were carried out on Sept. 24, 2004 and Oct. 14, 2004. In addition, a multipanel gillnet sample was collected on Sept. 28, 2004 (Figure 35). The mean length for this variable mesh size multi-panel sample was 29.3 cm and with almost all fish (only 4% males spent) in spawning condition. The calculated TS for a 120 kHz sounder based on this sample is -36.09 dB/kg (Table 2).

The first structured acoustic survey on the Eastern Shore fishing grounds was carried out on Sept. 24, 2004 by a single herring gillnet vessel, the *Bradley K.* Transects were completed in both a north to south (vertical) and east to west (horizontal) directions in a relatively small area of 0.7 km^2 where fishing had recently taken place (Figure 36). The estimate of 13,400t for the vertical north-south lines had a standard error of 12% and is based on target strength from a multipanel gillnet sample collected on Sept 28 (Table 2, Figure 35).

The second structured acoustic survey on the Eastern Shore fishing grounds was carried out on Oct. 8, Oct. 10 and Oct. 14, 2004 by a single herring gillnet vessel (Figure 37). Herring were surveyed near Musquodoboit Shoal on Oct. 8 with 3 transects completed. The acoustic unit was also operated on Oct. 10 off Jeddore but only one line was done and no fish were observed.

On Oct 14 a school south of Jeddore Head was covered with 3 lines completed followed by a subsequent more intensive survey of a larger school off Owls Head. The latter survey was somewhat hampered by weather conditions and boats fishing on the main school. Transects on the Owls Head group were completed in both east to west (11 lines) and north to south (4 lines) directions in a relatively small area of 1.2 - 1.4 km^2 where fishing was actively taking place. The data from various schools were estimated separately and the results were summed. The total biomass estimate from the two areas and survey nights with useable data is 15,000t with a standard error of 15% (Table 13) and is based on target strength derived from the Sept. 28 multipanel sample. One sample collected by industry for maturity on Oct. 20 showed all fish in mature condition with 77% spawning, 13% hard and 11% spent.

The final 2004 SSB estimate (using the ICF) for the Eastern Shore/Jeddore area based on the Sept. 18 and Oct. 14 acoustic surveys was 28,400t (Table 13).

Glace Bay:

In Sept. 2004 an acoustic recording system was installed on the herring gillnet vessel *Natasha Lee* based out of Glace Bay, N.S. Initial test recordings were completed from Sept. 9-12 and problems were encountered with the system power supply which resulted in fragmented data files (Figure 38). These difficulties were not resolved in time for the spawning fishery which took place during October with a total of 1,480t of spawning fish landed. Fishery samples from Oct. 6 to Oct. 20 were all mature with over 90% in spawning condition (Figure 39). As a result of the lack of mapping or acoustic survey data there was no estimate of spawning stock biomass for the Glace Bay area in 2004.

Bras d'Or Lakes:

In 2003 and 2004 no surveys were conducted to document the abundance of spawning herring in the Bras d'Or Lakes. The last mapping survey was conducted in 2000 and documented only 70t. No biological data were collected in 2004.

Offshore Scotian Shelf Component:

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf have varied between 1,000 and 20,000t since 1996 with landings of 4,165t in 2004. Acoustic recorders were activated on a few occasions but insufficient quantities of fish were observed to warrant analysis. Consequently, no acoustic biomass estimates were available from the Scotian Shelf. There was again no fall herring research survey on the Scotian Shelf using the research vessel CCGS *Alfred Needler*.

Chebucto Head (January 2004-2005):

There was no exploratory survey activity in the Chebucto Head area in January 2004. In January 2005, one vessel did some exploratory searching off Chebucto Head in the approaches to Halifax Harbour but found no aggregations of significance and did not record any fish (Figure 40).

DISCUSSION:

In 2004, as in previous years, the spawning stock biomass for the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex was determined primarily from industry based surveys of the three major spawning components: Scots Bay, Trinity Ledge, and German Bank. No structured surveys were conducted outside the main spawning areas, either around Seal Island or in the vicinity of Browns Bank, due to the absence of fleet activity in the area. There was also no activity in the Spectacle Buoy area in June.

This is the eighth season of surveying in which biomass estimates from industry based surveys have played a significant role in the evaluation of the 4WX herring stock abundance. For 2004 the majority of acoustic surveys in the Bay of Fundy/Southwest Nova Scotia areas were well organized and provided good coverage of the spawning grounds. The survey vessels generally completed the assigned transects and automated recording systems were distributed throughout the fleet on survey nights. The main deficiency in 2004 was the absence of structured surveys during October on German Bank. Coverage of Trinity Ledge was less than optimal and the spawning stock biomass is unlikely to be representative of the amount of fish spawning in the area. The set of surveys are considered to be comparable to others in the series since 1999.

The observed SSB for Scots Bay in 2004 decreased from the previous year. Sufficient time (10-14 days) had elapsed between surveys and coverage was good but equipment problems may have compromised some of the survey estimates. Spawning fish were again observed later in the season, into early September. The biomass estimates of herring observed on the four survey nights and one fishing night were added to provide an SSB of 106,700t for the component.

There were problems with the surveying of Trinity Ledge again this year and it is unlikely that biomass estimates reflect the abundance of fish. There has been a tendency for the survey vessels to concentrate on a relatively small area where the fish are known to aggregate. Structured multi-vessel surveys covering the entire spawning area of 200 km^2 seem to have been abandoned. Improvements to the survey approach and adherence to the design protocols are required if the data are to reflect trends in abundance. Trinity Ledge once supported a large spawning component within the 4WX stock complex. As such, given the fact that the observed biomass is still reduced, any fishing on Trinity Ledge must strictly adhere to the "survey, assess, then fish" protocol during the upcoming spawning season. This means that no fishing should occur until sufficient quantities of herring are observed to allow for removals. Alternatively, given the slow rate of recovery consideration should also be given to complete closure until a significant increase in spawning biomass is observed.

In 2004, the total spawning stock biomass observed on German Bank was estimated to be 343,500t (Table 9). The SSB is based on estimates of biomass from only 3 structured surveys undertaken from Sept. 2 to Sept. 30. The elapsed time between all surveys was within the 10-14 day guideline and turnover of spawners was assumed to be 100%.

Biomass estimates for the Nova Scotia coastal spawning component of the 4WX stock complex included acoustic and mapping survey data from Little Hope/Port Mouton and the Halifax/Eastern Shore area. There was a substantial decrease in the observed SSB (Table 14). There were no SSB estimates from the Glace Bay area, although an acoustic system was installed. In addition, no biomass estimates were made for the Bras d'Or Lakes or for the offshore Scotian Shelf banks. Large winter aggregations of herring off Chebucto Head have not been documented since January 2002. Finally, there continues to be a need to improve knowledge of all coastal Nova Scotia herring spawning areas.

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Table 1. Summary of the number of scheduled herring spawning ground surveys for 2004, the number of surveys undertaken and the number of fishing nights examined in the estimation of spawning stock biomass in the 4VWX stock complex. The number in brackets refers to the number of fishing nights for which data were analyzed.

Spawning Ground	Surveys Scheduled	Surveys Completed	Fishing Nights
Scots Bay	4	4	8 (1)
Trinity Ledge	3	3	0 (0)
German Bank	4	3	5 (0)
Eastern Shore	2	2	
Little Hope	2	2	
Glace Bay	2	0	
Total	17	14	13

Table 2. Summary of fish sampled, length/weight relationship, target strength estimate of samples, and target strength estimate for a 28 cm herring using the length/weight equation by survey date and location.

Date of Survey	Location of survey	Number Samples	Number Measured Fish	Number Len/Wt Fish	Mean Length (cm)	Mean Weight (gm)	Slope (log vs log regression)	Intercept (log vs log regression)	Target Strength dB/kg	Wt 28 cm Fish (gm)	TS 28 cm Fish dB/kg
19-Jul	Scots Bay fishing night	6	216	216	25.3	124	3.26	-5.75	-34.75	172	-35.31
02-Aug	Scots Bay	6	753	300	26.3	143	3.50	-6.32	-35.03	177	-35.43
16-Aug	Scots Bay	7	954	471	26.5	145	3.60	-6.56	-35.03	175	-35.40
29-Aug	Scots Bay	10	1277	547	26.4	142	3.49	-6.29	-34.97	174	-35.35
12-Sep	Scots Bay	4	592	271	27.1	153	3.50	-6.33	-35.09	172	-35.30
25-Aug	Trinity Ledge[1,2]				27.4	153			-35.53		
07-Sep	Trinity Ledge[1]	1	107	95	27.4	156	3.39	-6.07	-35.53	168	-35.66
02-Sep	German Bank	5	580	416	26.1	138	3.549	-6.44	-34.95	176	-35.42
16-Sep	German Bank	6	700	561	27.0	151	3.40	-6.08	-35.06	170	-35.27
30-Sep	German Bank	6	647	478	26.6	142	3.339	-5.94	-34.93	169	-35.24
02-Oct	Little Hope[1,3]				28.0	177			-35.66	177	-35.90
13-Oct	Little Hope[1,3]				28.0	177			-35.66	177	-35.90
18-Sep	East. Passage[1,4]	1	104	104	29.3	203	2.968	-5.01	-36.09	177	-35.90
14-Oct	East. Passage[1,4]				29.3	203			-36.09		

[1] TS adjust by -0.46 dB to account for difference in acoustic signal from 120 kHz system.

[2] TS estimated using mean length and length/weight relationship from Trinity Ledge Sept 7 multi-mesh sample.

[3] TS estimated for 28cm herring using length/weight relationship from Eastern Shore Sept 28 multi-mesh sample.

[4] TS estimated using mean length and length/weight relationship from Eastern Shore Sept 28 multi-mesh sample.

Table 3. Maturity staging for fresh herring as applied by the St. Andrews Biological Station herring investigation in comparison to Scotia Garden Seafood plant maturity stages and with estimated time to spawn

Stage	SABS Stage Name	Industry Stage Name	Time to Spawning	Female Herring Gonad Definition (from Parrish and Saville, 1965)
1	Immature 1		Year or more	Virgin herring. Ovaries very small 1-3mm broad, wine-red or pinkish color.
2	Immature 2		Year or more	Virgin herring with small sexual organs. Width of ovaries about 3-8mm, eggs not visible to naked eye but can be seen with magnifying glass, oval in cross-section, wine-red or pinkish.
3	Ripening 1		This season, months to go	Ovaries about half the length of body cavity. Width between 1-2 cm, distal end is torpedo shaped, eggs small but can be distinguished with naked eye, overall color is orange.
4	Ripening 2		Months or Weeks	Ovaries almost as long as body cavity. Eggs larger, varying in size, eggs opaque. Overall color is orange or pale yellow.
5	Ripe / Hard	Immature / Hard	Weeks or Days	Ovaries fill body cavity. Yellowish in color. Eggs large, round; some transparent but do not flow with pressure.
6	Spawning	Mature (small, bloody, white)	0 days, Now	Ovaries ripe. Eggs transparent and flowing freely.
7	Spent	Spent	Spawned days or weeks previously	Spent herring. Ovaries baggy and bloodshot, empty or containing only a few residual eggs.
8	Recovering / Resting		1 year	Recovering spent. Ovaries firm and larger than virgin herring at stage 2. Eggs not visible to naked eye. Walls of ovary striated, blood vessels prominent, dark wine-red in color. (This stage passes into Stage 3)
0	Undetermined			Unable to determine stage.

Table 4. Summary of 1987 to 2004 Scots Bay herring purse seine catches.

Year	Min. Date	Max. Date	No. Days	Catch t	No. Slips	Catch/Day	Catch/Slip
1987	08-Jul-87	06-Aug-87	30	3,398	91	113.25	37.34
1988	20-Jul-88	29-Jul-88	10	3,780	65	377.99	58.15
1989	19-Jul-89	13-Sep-89	57	6,021	164	105.64	36.72
1990	22-Jul-90	14-Aug-90	24	8,088	108	336.98	74.89
1991	05-Jul-91	14-Aug-91	41	7,365	163	179.63	45.18
1992	25-Jul-92	11-Aug-92	18	7,960	189	442.22	42.12
1993	25-Jul-93	01-Sep-93	39	5,228	100	134.04	52.28
1994	10-Jul-94	25-Aug-94	47	10,610	286	225.74	37.10
1995	24-Jul-95	26-Jul-95	3	907	33	302.33	27.48
1996	25-Jul-96	20-Aug-96	27	8,939	151	331.06	59.20
1997	30-Jul-97	27-Aug-97	29	4,847	91	167.14	53.26
1998	20-Jul-98	10-Sep-98	53	7,880	163	148.68	48.34
1999	19-Jul-99	17-Aug-99	30	1,789	40	59.63	44.73
2000	25-Jul-00	30-Aug-00	37	10,853	171	293.34	63.47
2001	10-Jul-01	21-Aug-01	43	10,739	176	249.74	61.02
2002	22-Jul-02	09-Sep-02	50	7,994	160	159.88	49.96
2003	21-Jul-03	05-Sep-03	47	19,196	237	408.43	81.00
2004	19-Jul-04	16-Sep-04	60	24,388	330	406.47	73.90

Table 5. Summary of the 2004 Scots Bay spawning ground acoustic survey data and associated biomass estimates. The total SSB for the spawning component is obtained by summing the biomass estimates.

a - without integration factor; as presented since 1997

Location/ Type	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Scots Bay									
Fishing Night	19-Jul-04	6	-42.56	0.166	25.3	-34.76	922	299	32%
Survey*	3-Aug-04	468	-49.59	0.036	26.3	-35.03	16,774	8,456	50%
Survey	16-Aug-04	475	-43.98	0.127	26.5	-35.03	60,437	27,804	46%
Survey*	29-Aug-04	640	-49.31	0.037	26.4	-34.97	23,673	15,484	65%
Survey	12-Sep-04	330	-52.38	0.009	27.1	-34.84	5,818	3,342	57%
* multi-frequency transducers				**Total SSB = 107,600t**			107,624	33,100	31%

b - with integration factor; introduced in 2004 assessment

Location/ Type	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Scots Bay									
Fishing Night	19-Jul-04	6	-42.03	0.187	25.3	-34.76	1,042	338	32%
Survey*	3-Aug-04	468	-49.56	0.036	26.3	-35.03	16,866	7,724	46%
Survey	16-Aug-04	475	-43.78	0.133	26.5	-35.03	63,327	27,804	44%
Survey*	29-Aug-04	640	-48.71	0.042	26.4	-34.97	27,110	18,269	67%
Survey	12-Sep-04	330	-51.765	0.010	27.1	-34.84	6,697	3,342	50%
* multi-frequency transducers				**Total SSB = 115,000t**			115,042	34,319	30%

Table 6. Summary of the 2004 herring biomass estimates observed during fishing nights in Scots Bay. The vessel names are *Dual Venture* (DV), *Lady Melissa* (LM), *Leroy & Barry* (LB) and *Secord* (SC). Only the estimate for July 19, 2004 was used in the final 2004 Scots Bay SSB.

Location	Vessel	Date	Area (km^2)	Weighted Sa (db/m^2)	Density (kg/m^2)	Target Strength	Biomass (t)	Standard Error (%)
Scots Bay	**SC**	**19-Jul-04**	**6.00**	**-42.03**	**0.19**	**-34.8**	**1,042**	**32**
Scots Bay	LM	25-Jul-04	11.00	-53.89	0.01	-35.5	160	32
Scots Bay	LM	04-Aug-04	4.50	-44.76	0.12	-35.5	533	32
Scots Bay	LB/DV	05-Aug-04	2.00	-35.80	0.93	-35.5	1,865	341
Scots Bay	LB	08-Aug-04	0.25	-30.42	3.22	-35.5	805	183
Scots Bay	DV	10-Aug-04	0.50	-32.39	2.05	-35.5	1,023	69
Scots Bay	LB/DV	11-Aug-04	4.50	-32.86	1.84	-35.5	8,263	116
Scots Bay	LM	18-Aug-04	1.60	-39.87	0.37	-35.5	585	298

Table 7. Summary of the 2004 Trinity Ledge acoustic surveys and SSB biomass estimates. Total SSB was estimated from biomass on Aug. 25 and Sept. 7 surveys.

a - without integration factor; as presented since 1997

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Trinity Ledge									
Acoustic	**25-Aug-04**	**12.0**	**-41.43**	**0.257**	**27.4**	**-35.53**	**3,072**	**537**	**17%**
Acoustic	5-Sep-04	0.7	-32.89	1.838	27.4	-35.53	1,287	226	18%
Acoustic	**7-Sep-04**	**0.8**	**-29.20**	**4.299**	**27.4**	**-35.53**	**3,439**	**911**	**26%**
				Total SSB = 6,500t			**6,511**	**1,057**	**16%**

b - with integration factor; introduced in 2004 assessment

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Trinity Ledge									
Acoustic	**25-Aug-04**	**12.0**	**-38.77**	**0.475**	**27.4**	**-35.53**	**5,672**	**992**	**17%**
Acoustic	5-Sep-04	0.7	-30.22	3.394	27.4	-35.53	2,376	416	18%
Acoustic	**7-Sep-04**	**0.8**	**-26.53**	**7.938**	**27.4**	**-35.53**	**6,350**	**1,682**	**26%**
				Total SSB = 12,000t			**12,022**	**1,953**	**16%**

Table 8. Summary of 1985 to 2004 German Bank herring purse seine catches.

Year	Min. Date	Max. Date	No. Days	Catch t	No. Slips	Catch/Day	Catch/Slip
1985	22-Jun-85	08-Oct-85	109	23,084	428	211.78	53.93
1986	18-Jun-86	01-Oct-86	106	15,892	349	149.92	45.53
1987	26-May-87	14-Oct-87	142	18,357	403	129.27	45.55
1988	29-May-88	06-Oct-88	131	33,125	610	252.86	54.30
1989	28-May-89	15-Oct-89	141	14,148	313	100.34	45.20
1990	23-May-90	23-Oct-90	154	24,867	428	161.48	58.10
1991	02-Jun-91	15-Oct-91	136	30,127	621	221.53	48.51
1992	31-May-92	04-Oct-92	127	24,160	556	190.23	43.45
1993	24-May-93	29-Sep-93	129	9,003	192	69.79	46.89
1994	05-May-94	28-Sep-94	147	12,641	252	85.99	50.16
1995	05-Jun-95	06-Oct-95	124	21,773	301	175.59	72.34
1996	20-Jun-96	27-Oct-96	130	18,320	260	140.92	70.46
1997	11-Jul-97	14-Oct-97	96	19,119	327	199.16	58.47
1998	10-Jun-98	14-Oct-98	127	24,720	516	194.64	47.91
1999	20-Apr-99	20-Oct-99	184	34,909	666	189.72	52.42
2000	18-Apr-00	26-Oct-00	192	35,977	598	187.38	60.16
2001	22-May-01	20-Oct-01	152	27,468	521	180.71	52.72
2002	18-Apr-02	12-Oct-02	178	30,806	643	173.07	47.91
2003	05-May-03	15-Oct-03	164	28,970	392	176.65	73.90
2004	10-May-04	15-Oct-04	159	18,025	238	113.36	75.74

Table 9. Summary of the 2004 German Bank spawning ground acoustic survey results and SSB biomass estimates.

a - without integration factor; as presented since 1997

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
German Bank									
Survey*	2-Sep-04	650	-42.74	0.169	26.1	-34.95	109,775	26,133	24%
Survey*	16-Sep-04	400	-39.17	0.388	27.0	-35.06	155,348	57,824	37%
Survey*	30-Sep-04	660	-43.05	0.155	26.6	-34.93	102,506	19,482	19%
* multi-frequency transducers				**Total SSB =367,600t**			367,629	66,378	18%

b - with integration factor; introduced in 2004 assessment

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
German Bank									
Survey*	2-Sep-04	650	-42.59	0.174	26.1	-34.95	113,333	27,006	24%
Survey*	16-Sep-04	400	-38.84	0.419	27.0	-35.06	167,502	62,255	37%
Survey*	30-Sep-04	660	-42.70	0.168	26.6	-34.93	111,120	22,637	20%
* multi-frequency transducers				**Total SSB = 392,000t**			391,955	71,536	18%

Table 10. Summary of the 2004 herring biomass estimates observed during fishing nights on German Bank. The vessel names are *Dual Venture* (DV), *Island Pride II* (IP), *Lady Melissa* (LM) and *Leroy & Barry* (LB). None of these estimates were used in the final 2004 German Bank SSB.

Location	Vessel	Date	Area (km^2)	Weighted Sa (db/m^2)	Density (kg/m^2)	Target Strength	Biomass (t)	Standard Error (%)
German Bank	LB	03-Oct-04	1.50	-28.27	5.28	-35.5	7,922	22
German Bank	DV/IP	04-Oct-04	13.00	-30.06	3.50	-35.5	45,534	15
German Bank	LB	05-Oct-04	0.20	-26.28	8.37	-35.5	1,673	0
German Bank	LM	06-Oct-04	10.00	-29.49	3.99	-35.5	39,939	28
German Bank	DV	07-Oct-04	10.00	-30.28	3.33	-35.5	33,271	19

Table 11. Summary of the minimum observed spawning stock biomass for each of the surveyed spawning grounds in the Bay of Fundy/SW Nova component of the 4WX stock complex. Total SSB is rounded to nearest 100t and all data was calculated without the use of the integration factor.

Location/Year	1997*	1998*	1999	2000	2001	2002	2003	2004	Average 1999-2004
Scots Bay	160,200	72,500	41,000	106,300	163,900	141,000	133,900	107,600	115,617
Trinity Ledge	23,000	6,800	3,900	600	14,800	8,100	14,500	6,500	8,067
German Bank	370,400	440,700	460,800	356,400	190,500	393,100	343,500	367,600	351,983
Spectacle Buoy									
- Spring	15,000	1,300	0	0	1,100		1,400		625
- Fall					87,500				87,500
Sub-Total	568,600	521,300	505,700	463,300	457,800	542,200	493,300	481,700	490,667
Seal Island					3,300	1,200	12,200		5,567
Browns Bank					45,800				45,800
Total	568,600	521,300	505,700	463,300	506,900	543,400	505,400	481,700	501,067
Overall SE t	n/a	n/a	94,600	64,900	50,800	49,500	86,100	74,200	70,017
Overall SE %	n/a	n/a	19	14	10	9	17	15	14

*Biomass estimates prior to 1999 are not considered comparable due to variation in the coverage area.

Table 12. Summary of the 2004 Little Hope/Port Mouton acoustic survey results and SSB biomass estimates. Note the standard TS was corrected to account for the frequency of the echo sounder (120 kHz). Highlighted surveys in bold were used to estimate total SSB for 2004

a - without integration factor; as presented since 1997

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Mapping	2-Oct-04	140					3,200		
Acoustic	**2-Oct-04**	**46**	**-41.59**	**0.255**	**28.0**	**-35.66**	**11,793**	**2,216**	**19%**
Acoustic	**13-Oct-04**	**2**	**-32.97**	**1.856**	**28.0**	**-35.66**	**3,805**	**567**	**15%**
				Total SSB = 15,600t			**15,598**	**2,288**	**15%**

b - with integration factor; introduced in 2004 assessment

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Mapping	2-Oct-04	140					3,200		
Acoustic	**2-Oct-04**	**46**	**-40.42**	**0.335**	**28.0**	**-35.66**	**15,469**	**2,975**	**19%**
Acoustic	**13-Oct-04**	**2**	**-30.31**	**3.428**	**28.0**	**-35.66**	**7,027**	**1,048**	**15%**
				Total SSB = 22,500t			**22,496**	**1,048**	**5%**

Table 11. Summary of the minimum observed spawning stock biomass for each of the surveyed spawning grounds in the Bay of Fundy/SW Nova component of the 4WX stock complex. Total SSB is rounded to nearest 100t and all data was calculated without the use of the integration factor.

Location/Year	1997*	1998*	1999	2000	2001	2002	2003	2004	Average 1999-2004
Scots Bay	160,200	72,500	41,000	106,300	163,900	141,000	133,900	107,600	115,617
Trinity Ledge	23,000	6,800	3,900	600	14,800	8,100	14,500	6,500	8,067
German Bank	370,400	440,700	460,800	356,400	190,500	393,100	343,500	367,600	351,983
Spectacle Buoy									
- Spring	15,000	1,300	0	0	1,100		1,400		625
- Fall					87,500				87,500
Sub-Total	568,600	521,300	505,700	463,300	457,800	542,200	493,300	481,700	490,667
Seal Island					3,300	1,200	12,200		5,567
Browns Bank					45,800				45,800
Total	568,600	521,300	505,700	463,300	506,900	543,400	505,400	481,700	501,067
Overall SE t	n/a	n/a	94,600	64,900	50,800	49,500	86,100	74,200	70,017
Overall SE %	n/a	n/a	19	14	10	9	17	15	14

*Biomass estimates prior to 1999 are not considered comparable due to variation in the coverage area.

Table 12. Summary of the 2004 Little Hope/Port Mouton acoustic survey results and SSB biomass estimates. Note the standard TS was corrected to account for the frequency of the echo sounder (120 kHz). Highlighted surveys in bold were used to estimate total SSB for 2004

a - without integration factor; as presented since 1997

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Mapping	2-Oct-04	140					3,200		
Acoustic	**2-Oct-04**	**46**	**-41.59**	**0.255**	**28.0**	**-35.66**	**11,793**	**2,216**	**19%**
Acoustic	**13-Oct-04**	**2**	**-32.97**	**1.856**	**28.0**	**-35.66**	**3,805**	**567**	**15%**
				Total SSB = 15,600t			**15,598**	**2,288**	**15%**

b - with integration factor; introduced in 2004 assessment

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Little Hope/Port Mouton									
Mapping	2-Oct-04	140					3,200		
Acoustic	**2-Oct-04**	**46**	**-40.42**	**0.335**	**28.0**	**-35.66**	**15,469**	**2,975**	**19%**
Acoustic	**13-Oct-04**	**2**	**-30.31**	**3.428**	**28.0**	**-35.66**	**7,027**	**1,048**	**15%**
				Total SSB = 22,500t			**22,496**	**1,048**	**5%**

Table 13. Summary of the 2004 Eastern Passage acoustic survey results and SSB estimates.

a - without integration factor; as presented since 1997

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Eastern Shore									
Acoustic	24-Sep-04	0.7	-25.21	12.25	29.3	-36.09	8,574	1,014	12%
Acoustic	14-Oct-04	1.9	-29.05	5.06	29.3	-36.09	9,615	1,396	15%
				Total SSB = 18,200 t			18,189	1,725	9%

b - with integration factor; introduced in 2004 assessment

Location	Date	Area (km^2)	Weighted Sa (dB/m^2)	Density (kg/m^2)	Mean Length (cm)	Target Strength (dB/kg)	Biomass (t)	Standard Error (t)	SE %
Eastern Shore									
Acoustic	24-Sep-04	0.7	-23.27	19.15	29.3	-36.09	13,403	1,585	12%
Acoustic	14-Oct-04	1.9	-27.11	7.91	29.3	-36.09	15,031	2,183	15%
				Total SSB = 28,400t			28,434	2,697	9%

Table 14. Summary of the estimated biomass for locations outside the Bay of Fundy/Southwest Nova Scotia quota area from 1998 to 2004. All areas are for individual spawning grounds and are estimates of SSB rounded to the nearest 100t.

Survey SSB (t)	1998	1999	2000	2001	2002	2003	2004
Little Hope/Port Mouton	14,100	15,800	5,200	21,300	56,000	62,500	15,600
Halifax/Eastern Shore	8,300	20,200	10,900	16,700	41,500	76,500	18,200
Glace Bay		2,000		21,200	7,700	31,500	n/a
Bras d'Or Lakes		530	70				

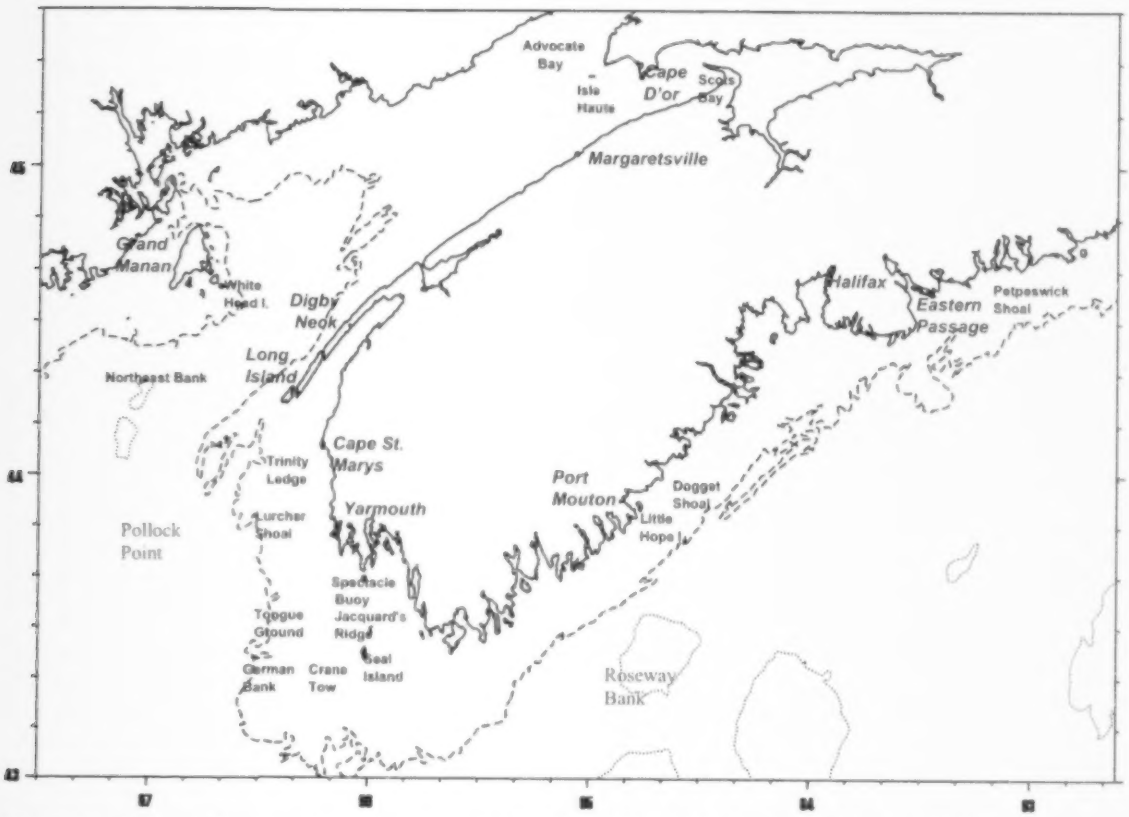

Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

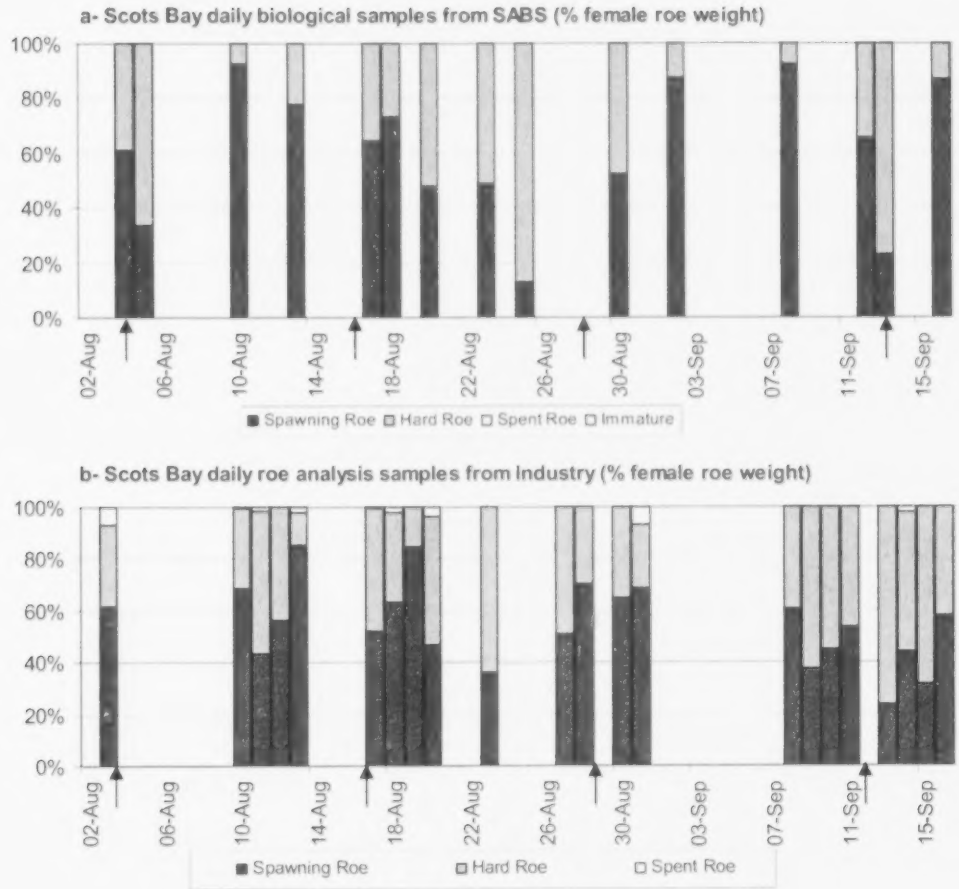

Figure 2. Daily herring female gonad maturity samples (% roe weight) for Scots Bay in 2004 for a) SABS samples and b) Industry samples. Arrows indicate dates of acoustic surveys.

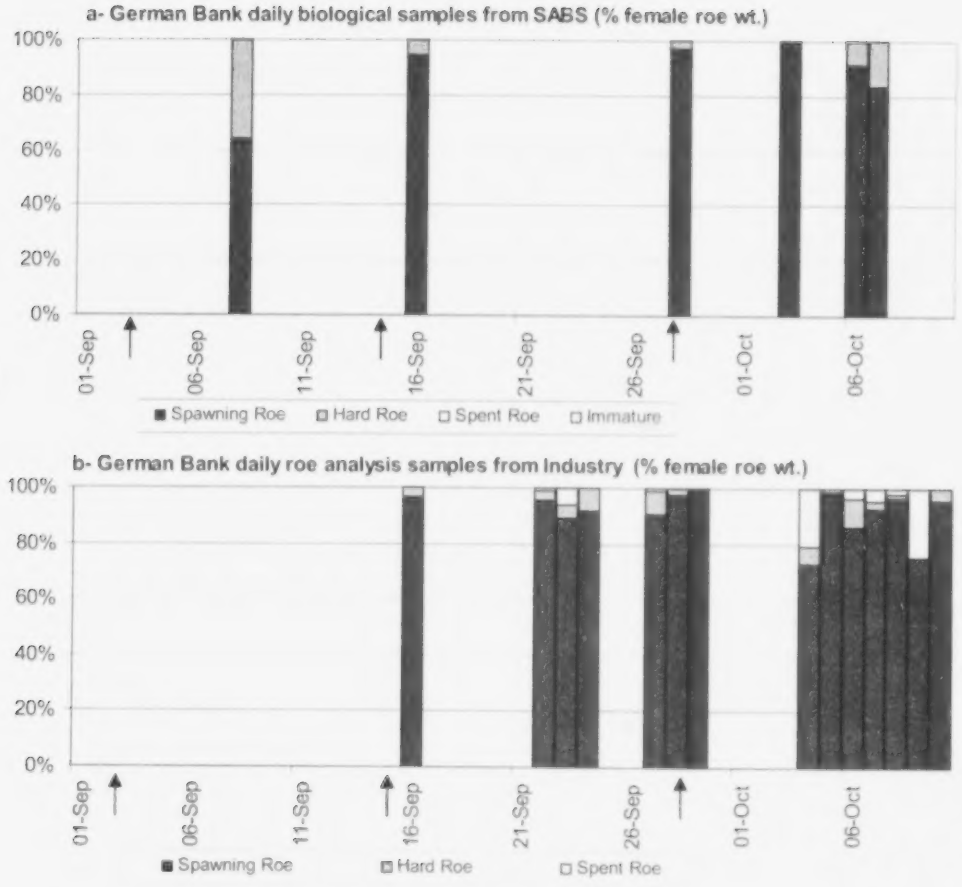

Figure 3. Daily herring female gonad maturity samples (% roe weight) for German Bank in 2004 for a) SABS samples and b) Industry samples. Arrows indicate dates of acoustic surveys.

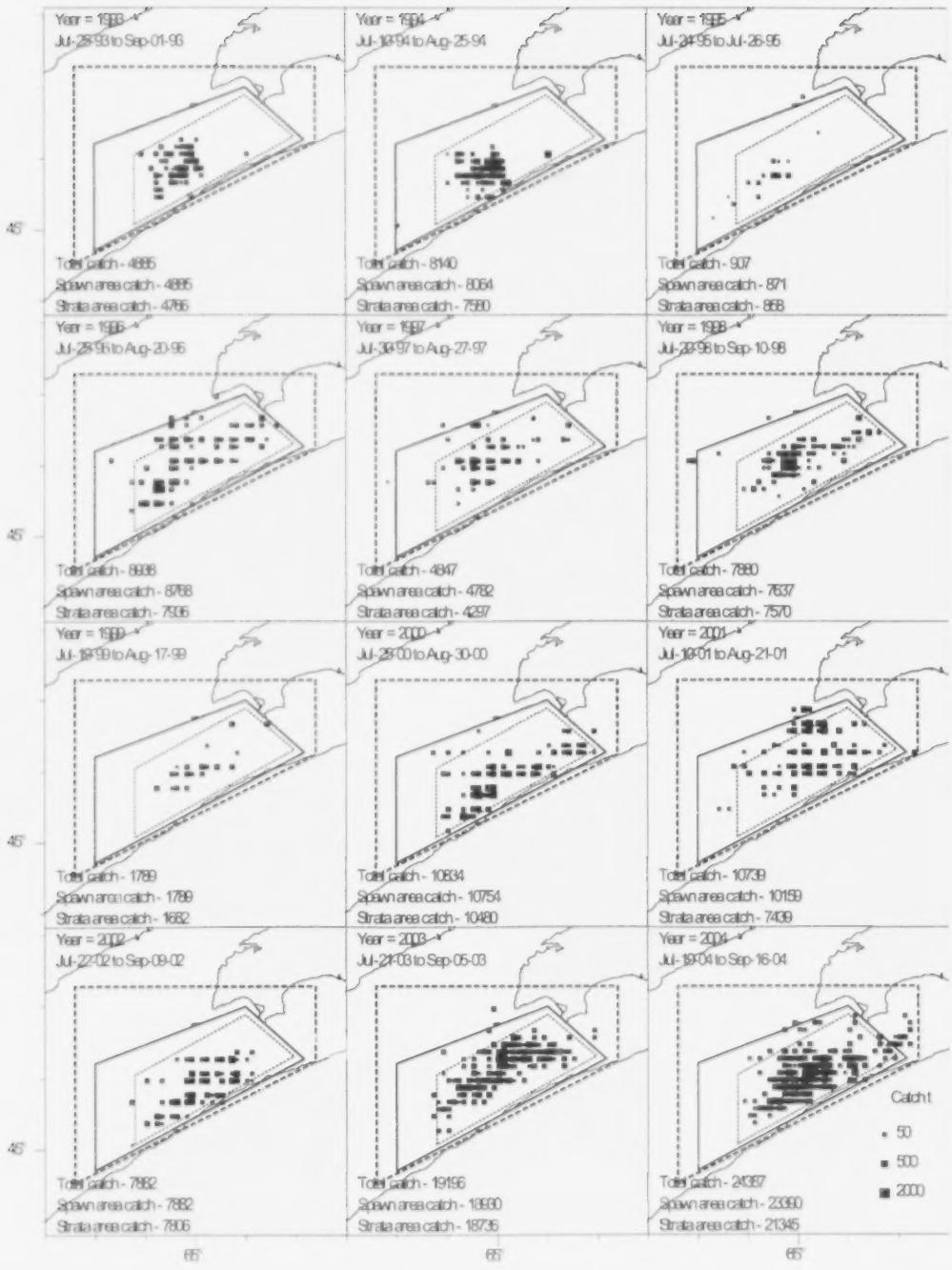

Figure 4. Herring purse seine catches for the Scots Bay area from 1993-2004 with catch totals for the overall area, the middle 'Spawning' area and the inner 'Strata' area which was used as the primary search area in acoustic surveys.

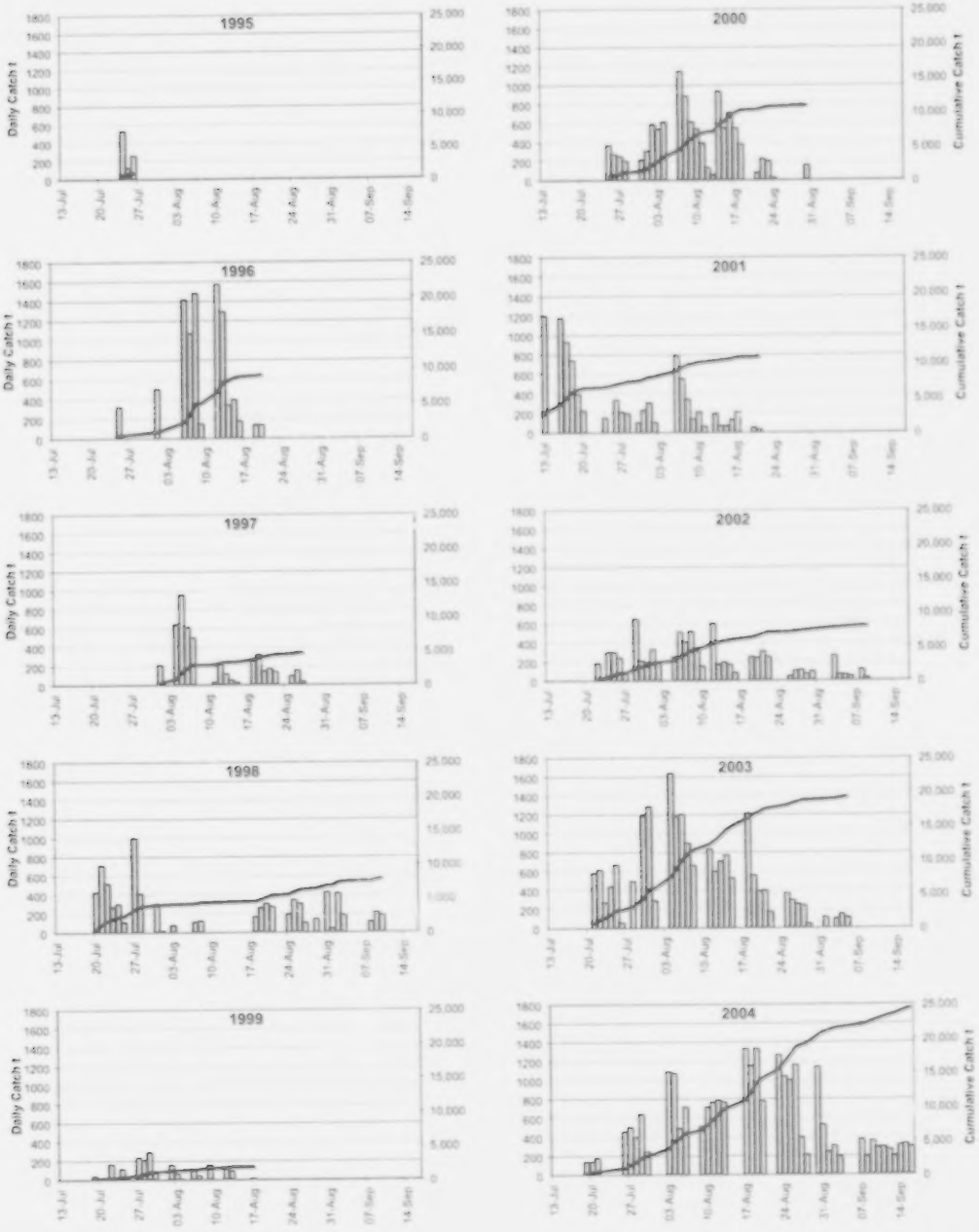

Figure 5. 1995 to 2004 daily purse seine herring catches in tonnes (bars) for Scots Bay with the cumulative total catch (solid line) over the entire fishing season.

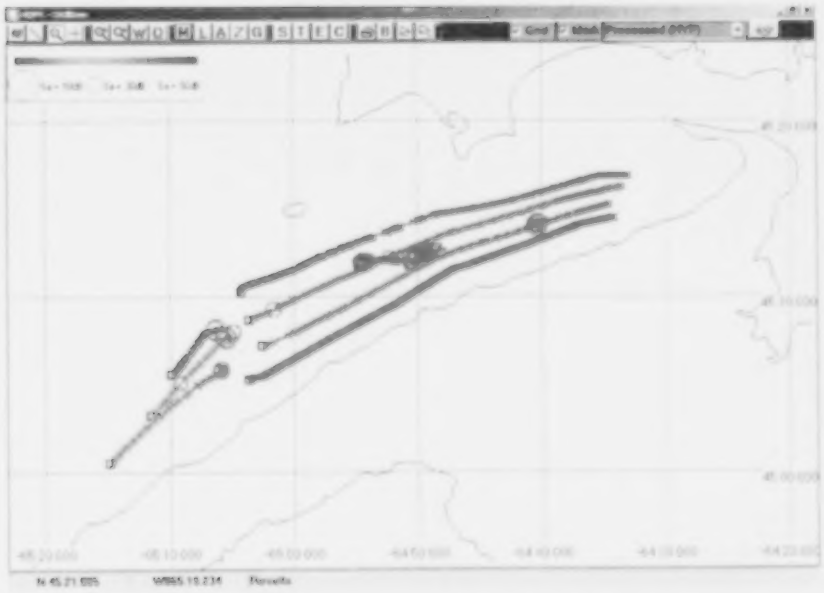

Figure 6. Scots Bay survey on Aug. 2-3, 2004 with acoustic transects showing location of targets including pre-survey (3 shorter lines to west), survey (4 long lines) and post-survey pre-set (short lines in middle of area).

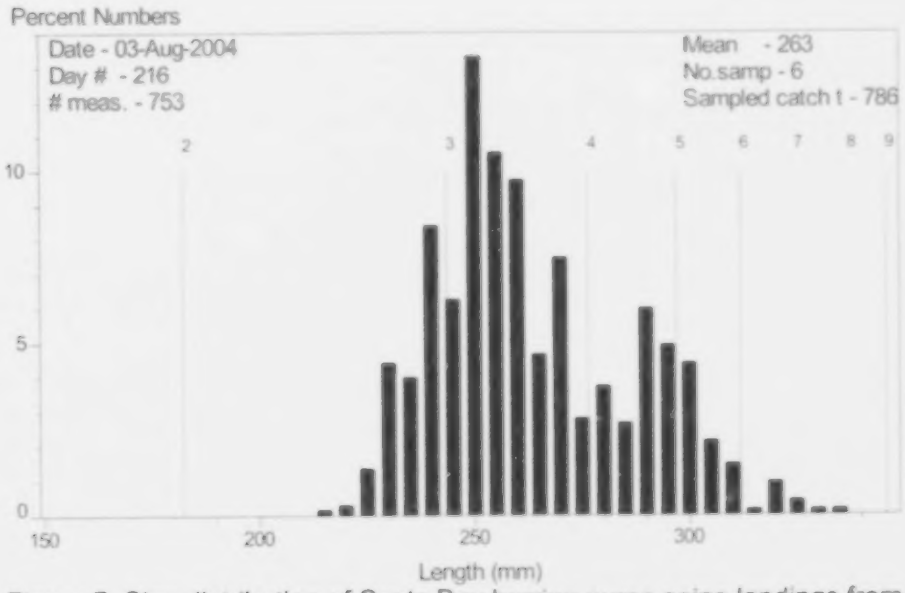

Figure 7. Size distribution of Scots Bay herring purse seine landings from samples collected on Aug. 3, 2004 (with mean August ages for 1970-2003).

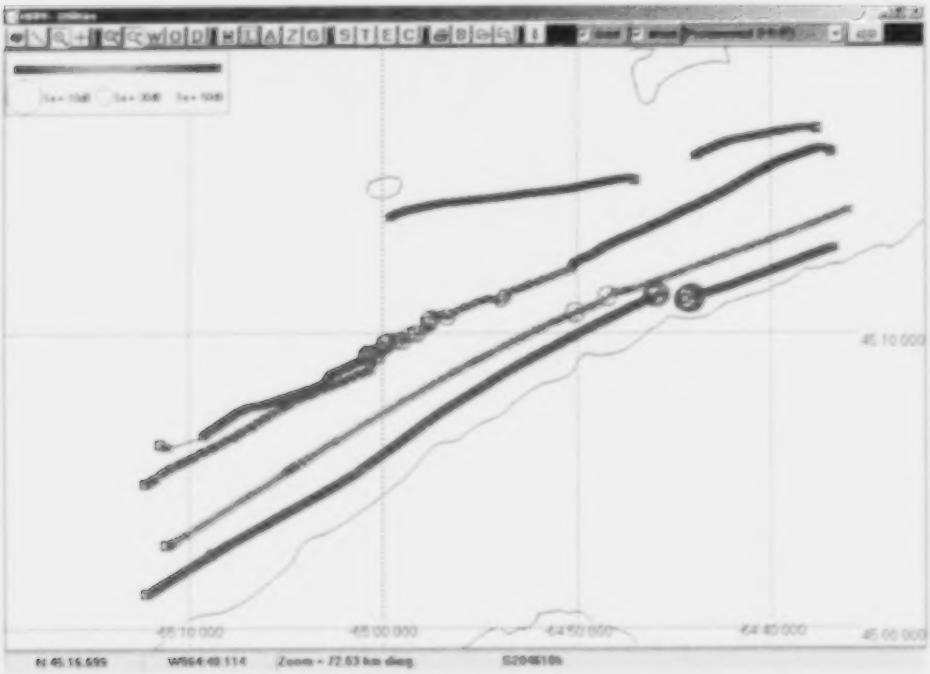

Figure 8. Scots Bay August 16, 2004 acoustic survey transects with location of targets along the transects shown as expanding circles.

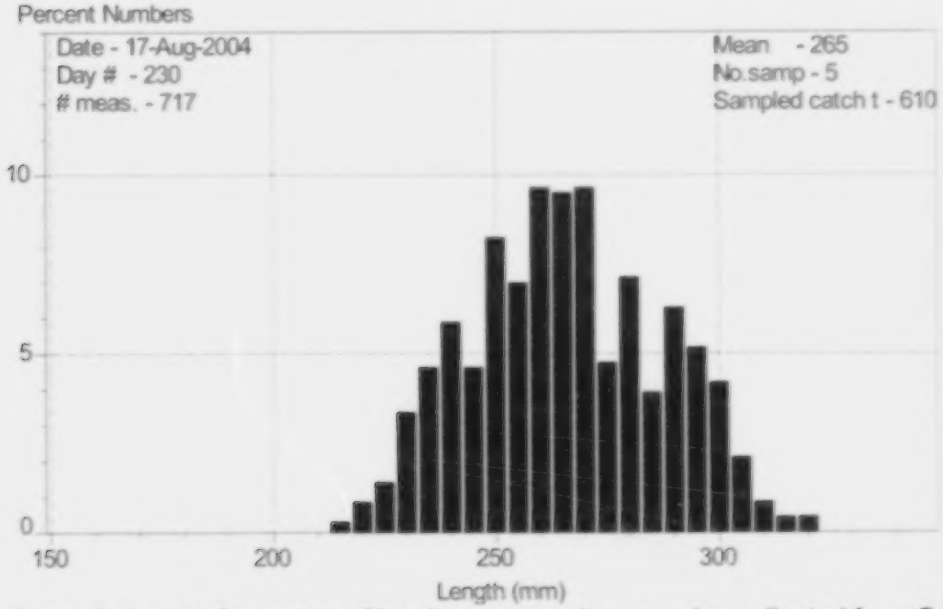

Figure 9. Length frequency of herring purse seine samples collected from Scots Bay landings on August 17, 2004.

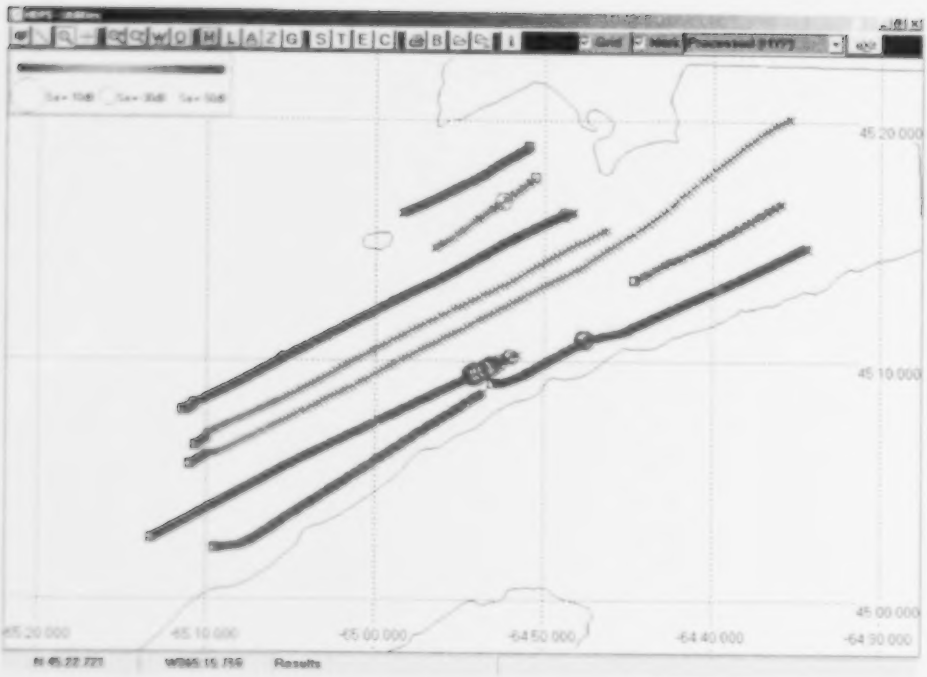

Figure 10. Scots Bay August 29, 2004 survey transects as used in the analysis with location of targets along shown as expanding circles.

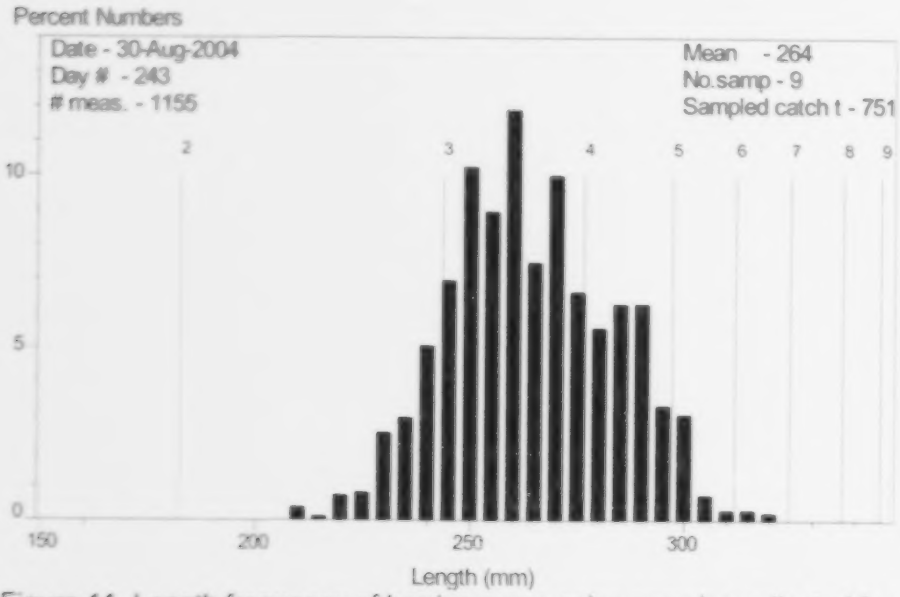

Figure 11. Length frequency of herring purse seine samples collected from Scots Bay landings on August 30, 2004 (with mean August ages for 1970-2003).

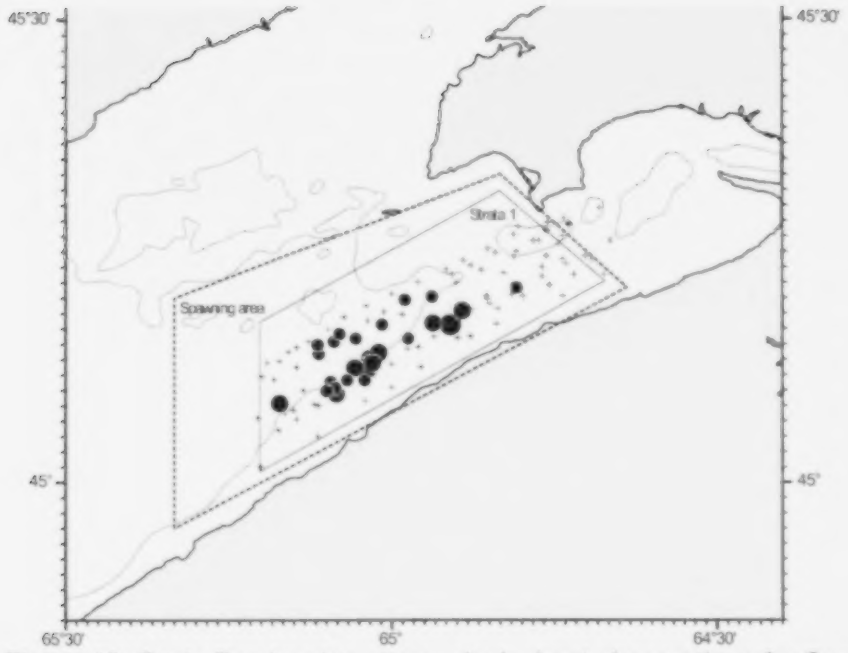

Figure 12. Scots Bay herring survey deck sheet observations for Sept. 12, 2004 with overall defined spawning area (dashed line box) and standard survey area or Strata 1 (solid line box).

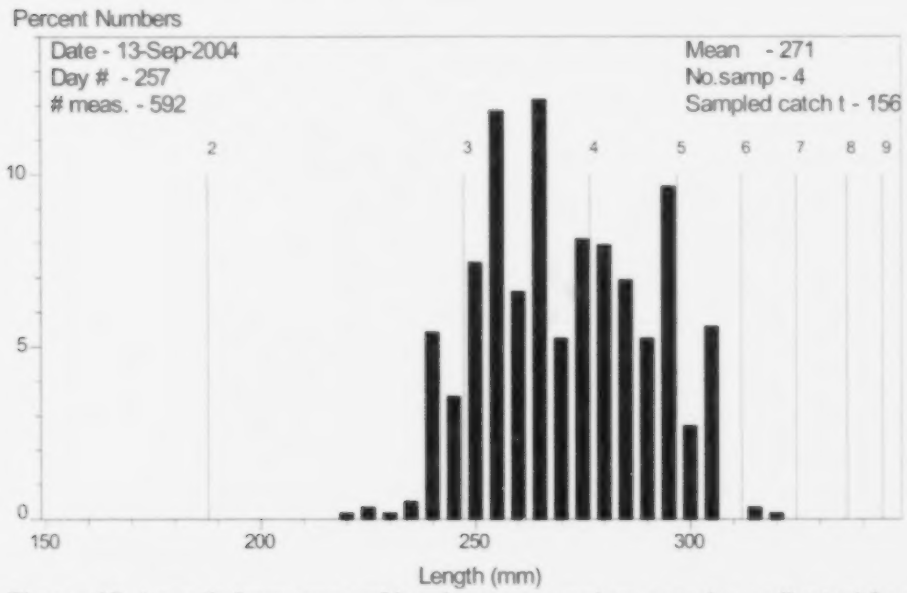

Figure 13. Length frequency of herring purse seine samples collected from Scots Bay landings on September 13, 2004 (with mean Sept. ages for 1970-2003).

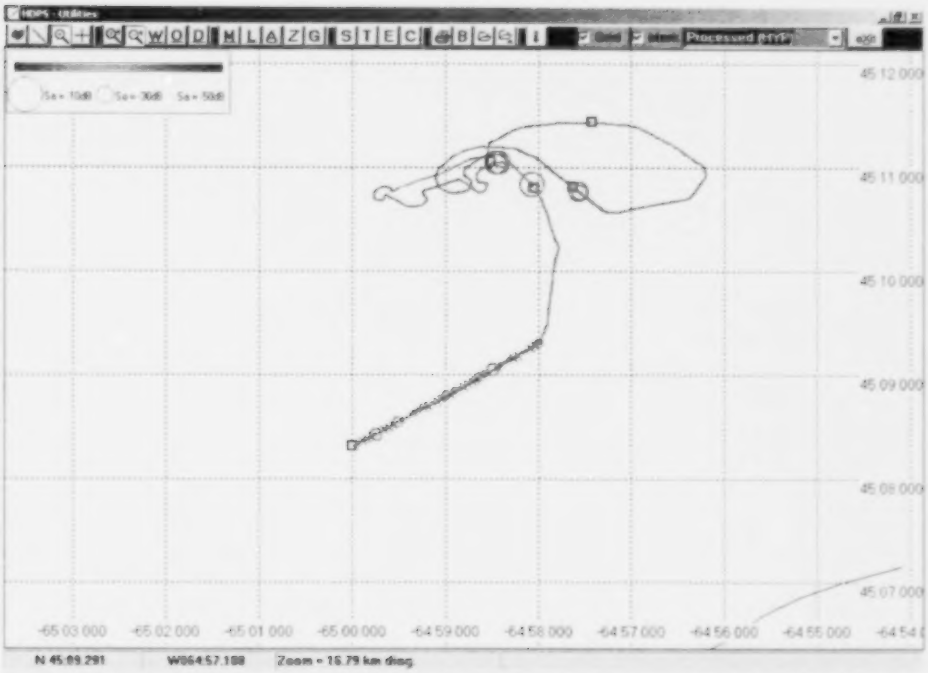

Figure 14. Fishing night survey by *Secord* in Scots Bay on July 19, 2004 showing search track and acoustic targets as expanding circles.

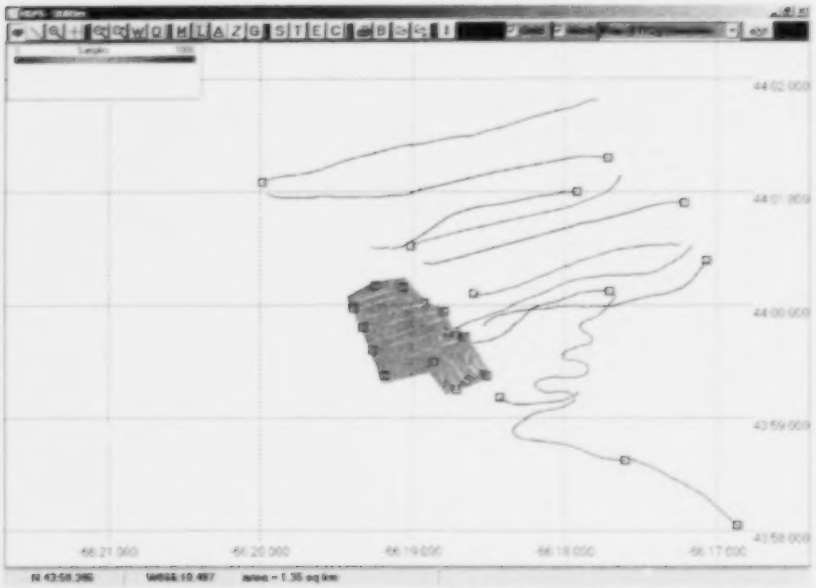

Figure 15. Trinity Ledge August 25, 2004 spawning ground survey with estimated coverage area of 1.35 km^2. Lines outside the enclosed area have an estimated area of 10.6 km^2.

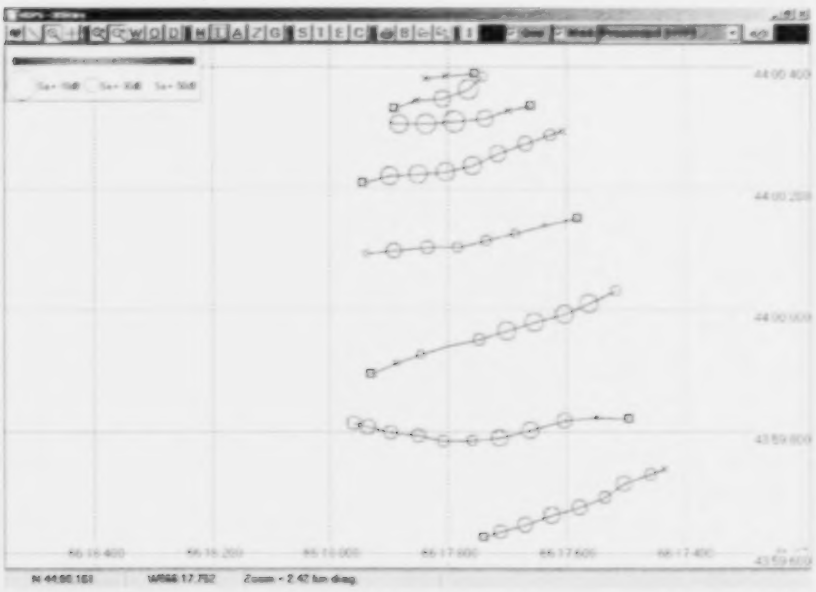

Figure 16. Trinity Ledge Sept. 7, 2004 survey transects with expanding circles representing average backscatter (Sa) (area=0.8 sq km).

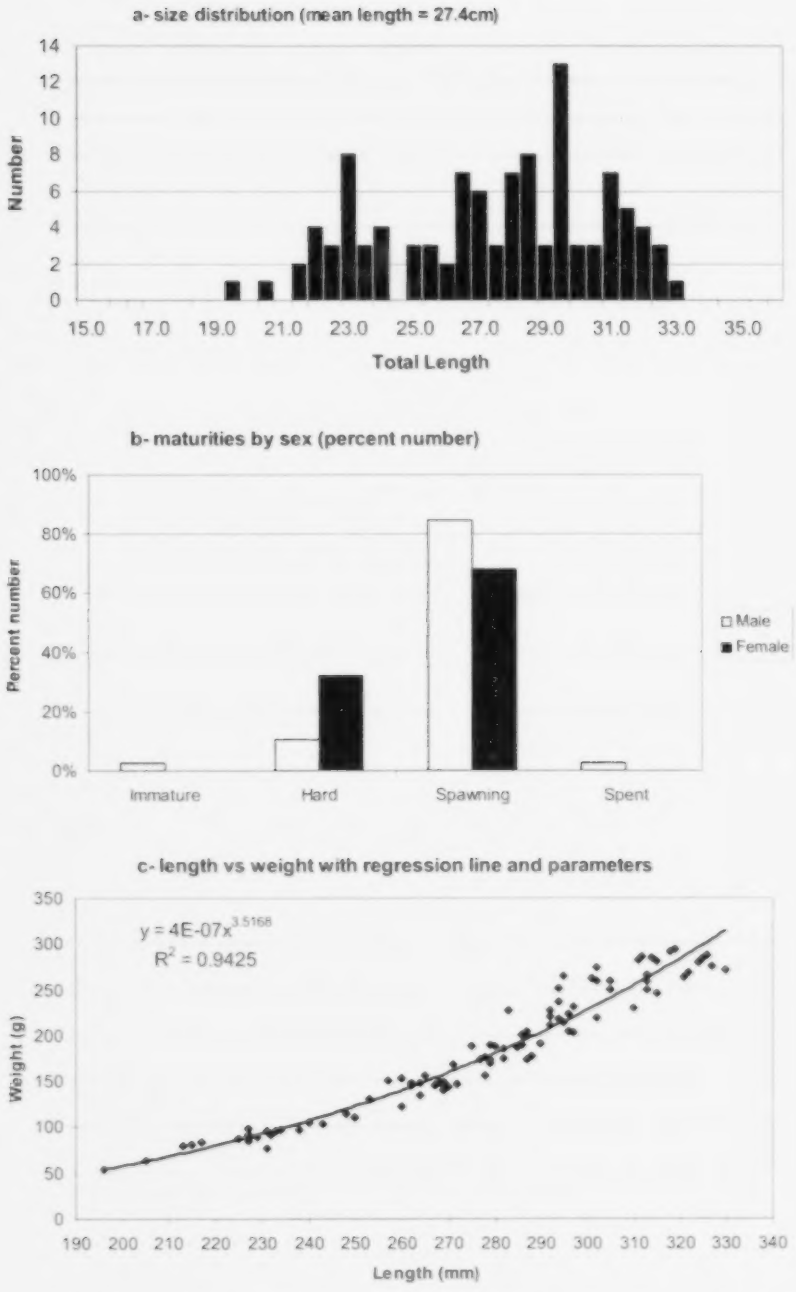

Figure 17. Sampling data for Trinity Ledge multipanel gillnet on Sept. 8, 2004 with a) size distribution b) maturity proportions by sex and c) regression of length vs weight.

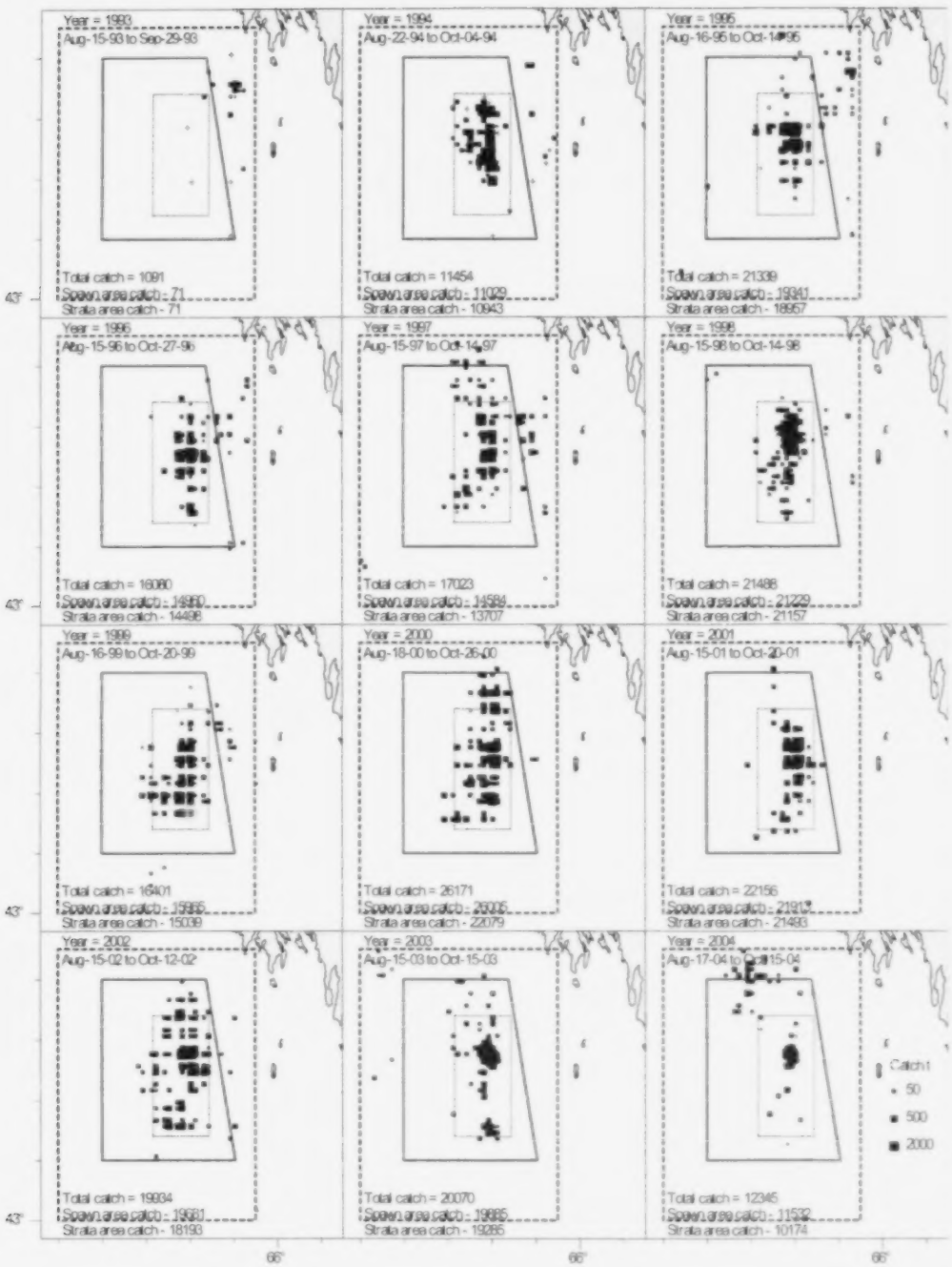

Figure 18. Herring purse seine spawning period catches (Aug 15 to Oct. 31) for German Bank from 1993-2004 with catch totals for the overall area, the middle 'Spawn Box' and the inner 'Strata Box' which was used as the primary search area in acoustic surveys.

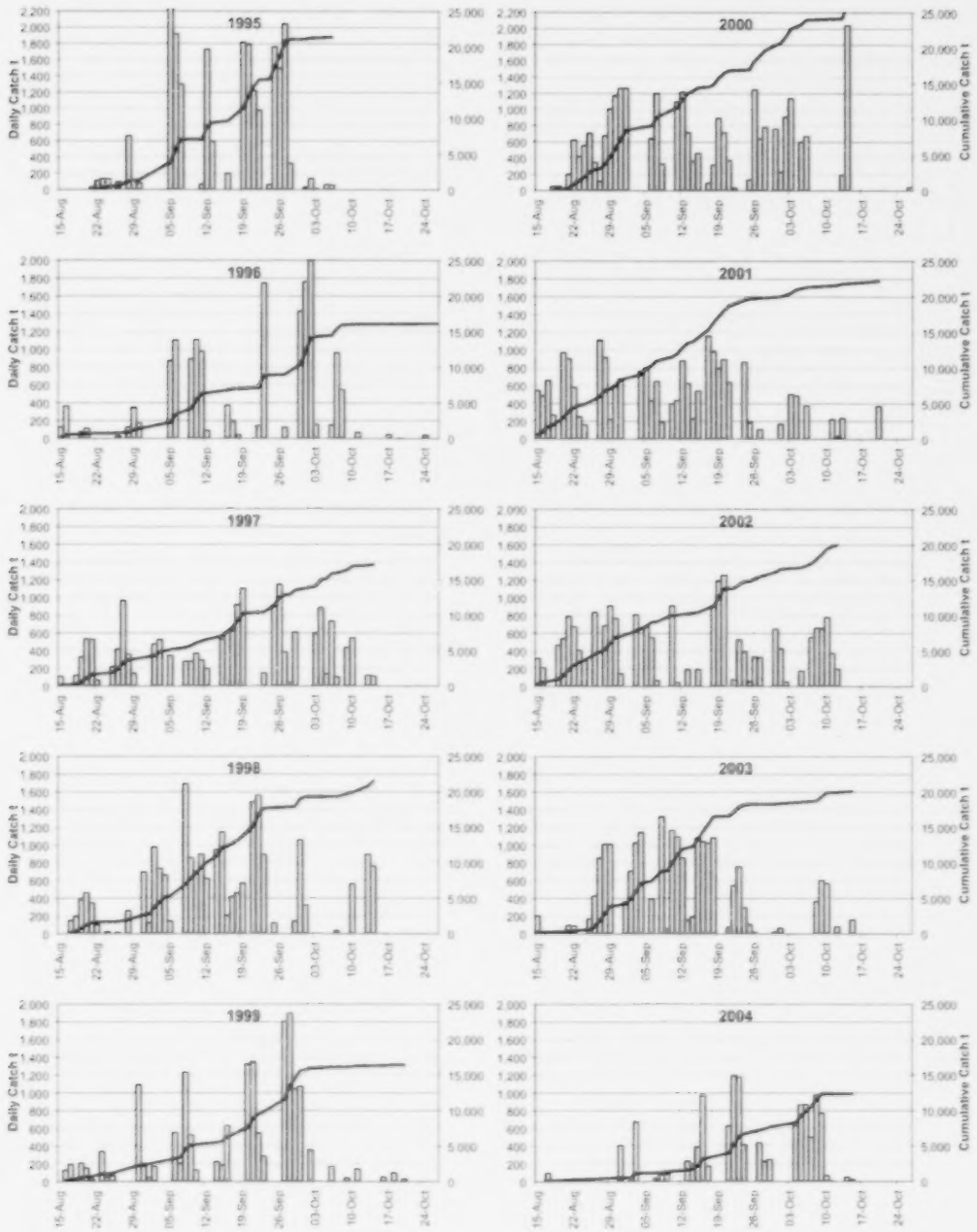

Figure 19. 1995 to 2004 daily purse seine herring catches in tonnes (bars) for German Bank with the cumulative total catch (solid line) over the spawning season from August 15 to October 30.

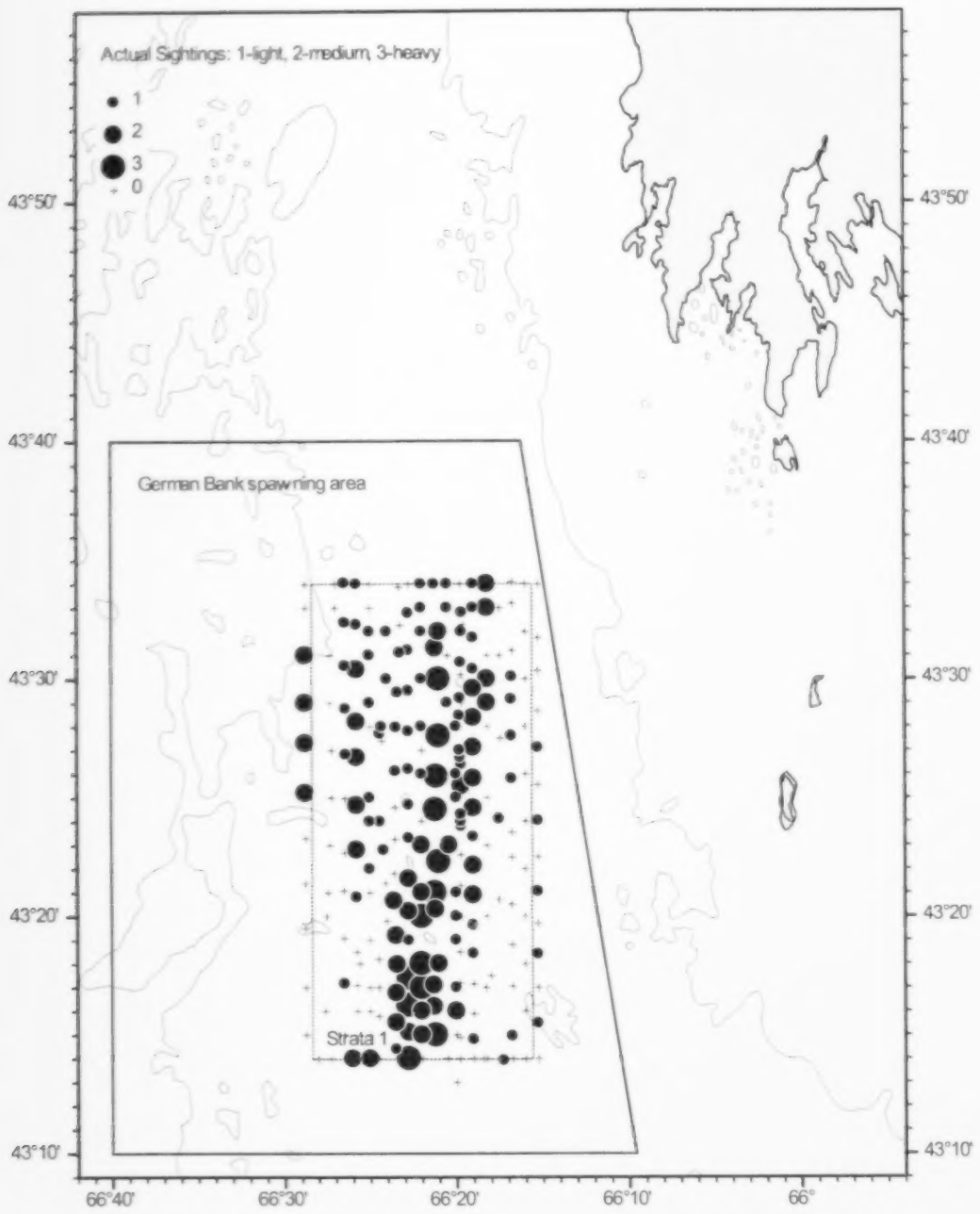

Figure 20. German Bank mapping survey results for Sept. 2-3, 2004 with dot size corresponding to density of fish sightings encountered. Overall spawning area (solid line) and standard survey area Strata 1 (dashed line) are also shown.

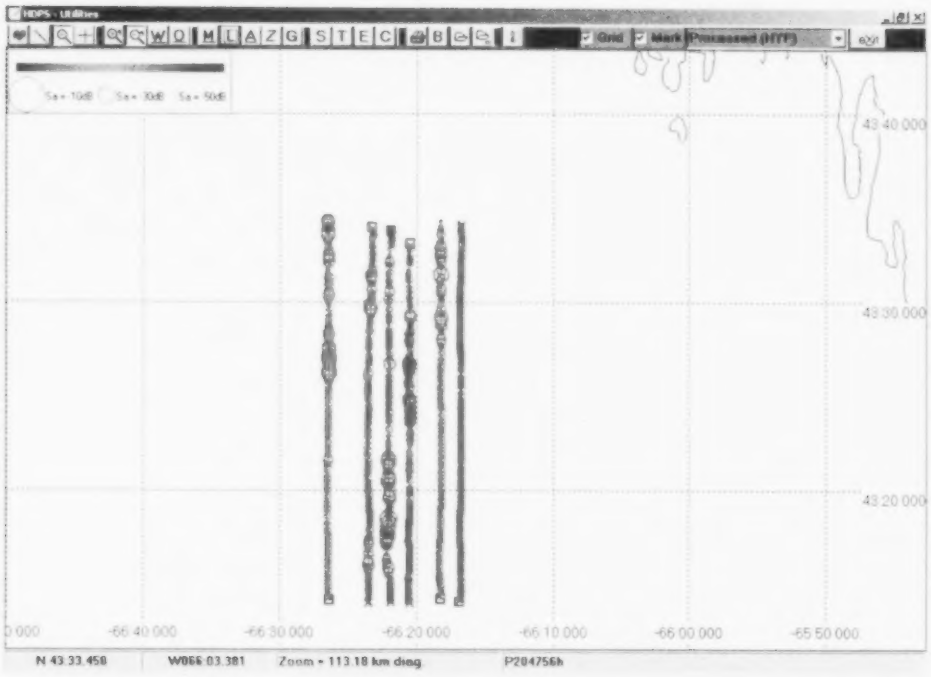

Figure 21. Acoustic transects for Sept. 2-3, 2004 German Bank survey showing location and density of herring observations from sounder recordings.

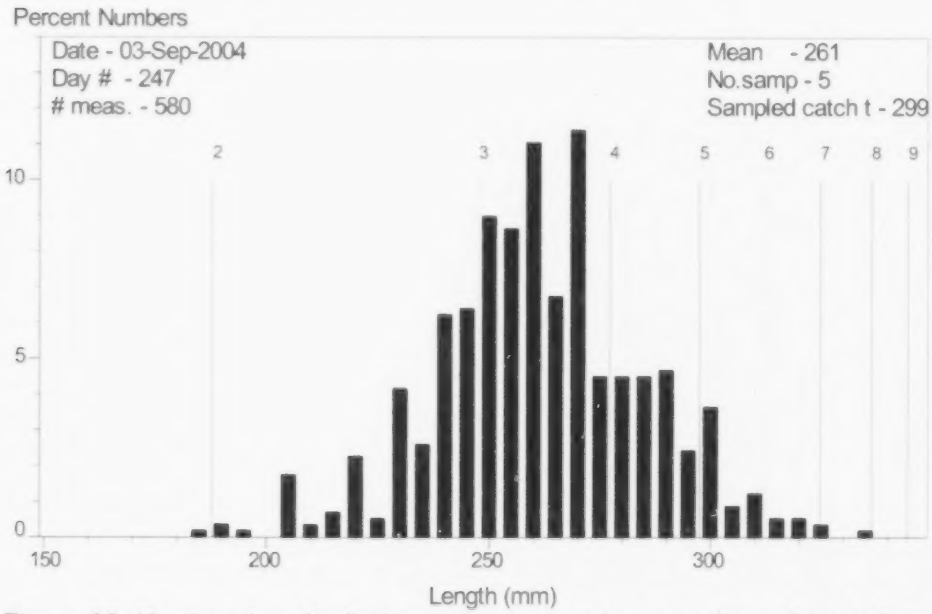

Figure 22. Herring size distribution from purse seine samples collected from German Bank landings on Sept. 3, 2004 (with mean Sept. ages from 1970-2003 historical samples).

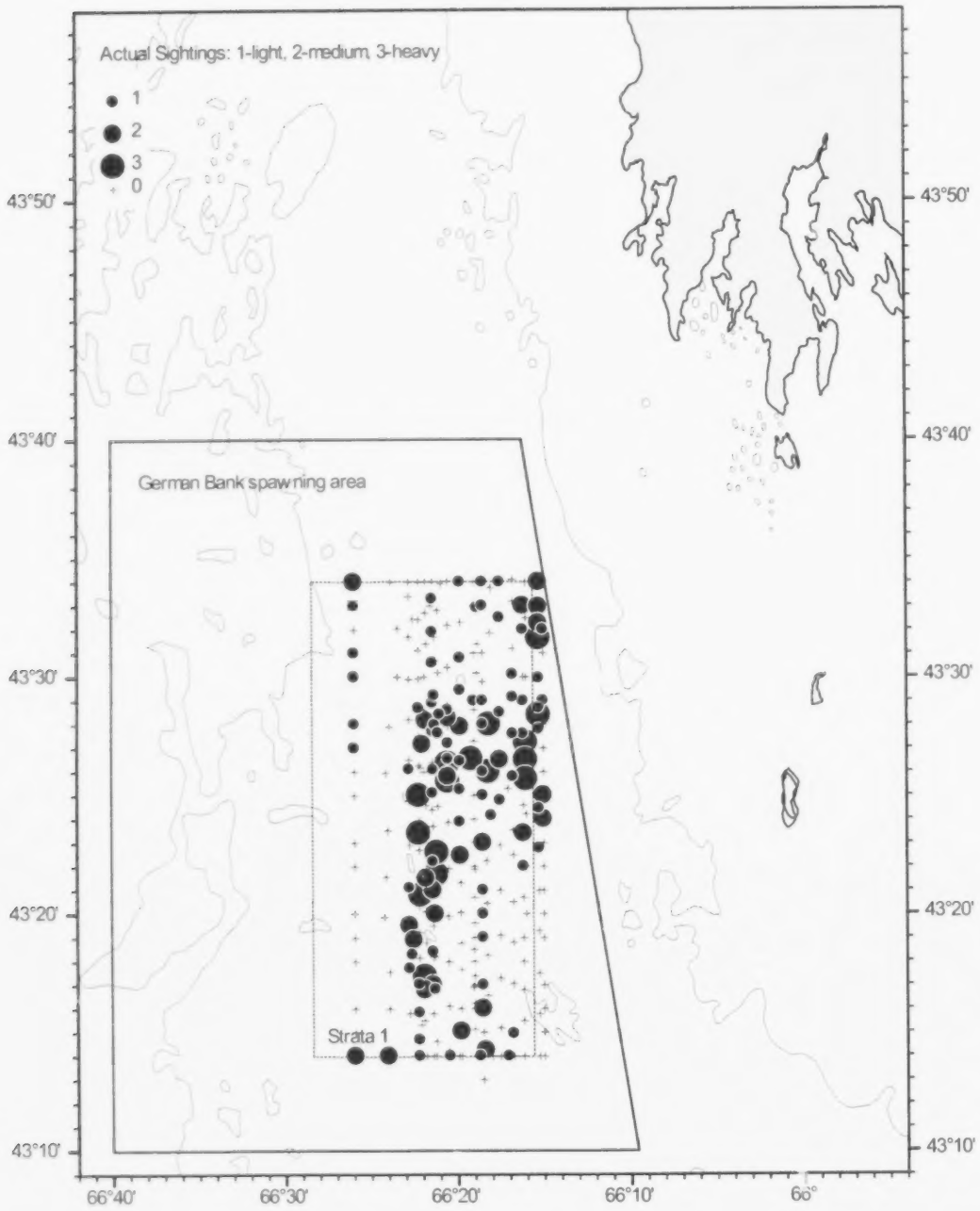

Figure 23. German Bank mapping survey results for Sept. 16-17, 2004 with dot size corresponding to density of fish sightings encountered. Overall spawning area (solid line) and standard survey area Strata 1 (dashed line) are also shown.

Figure 24. Acoustic transects for Sept. 16, 2004 German Bank survey showing location and density of herring observations from sounder recordings and estimation of survey area of 400 km^2.

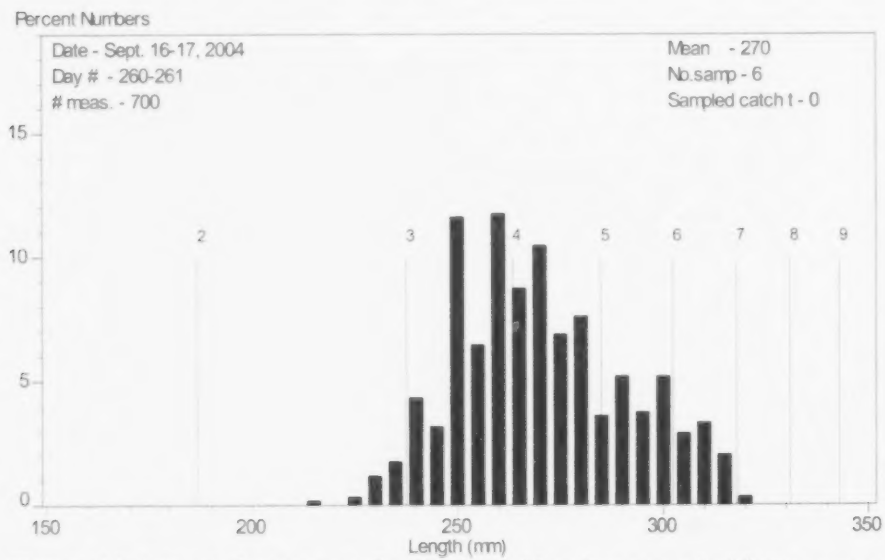

Figure 25. Length frequency distribution of herring sampled from purse seine catches on German Bank from September 16-17, 2004 (with mean September ages from 1994-2003 historical samples).

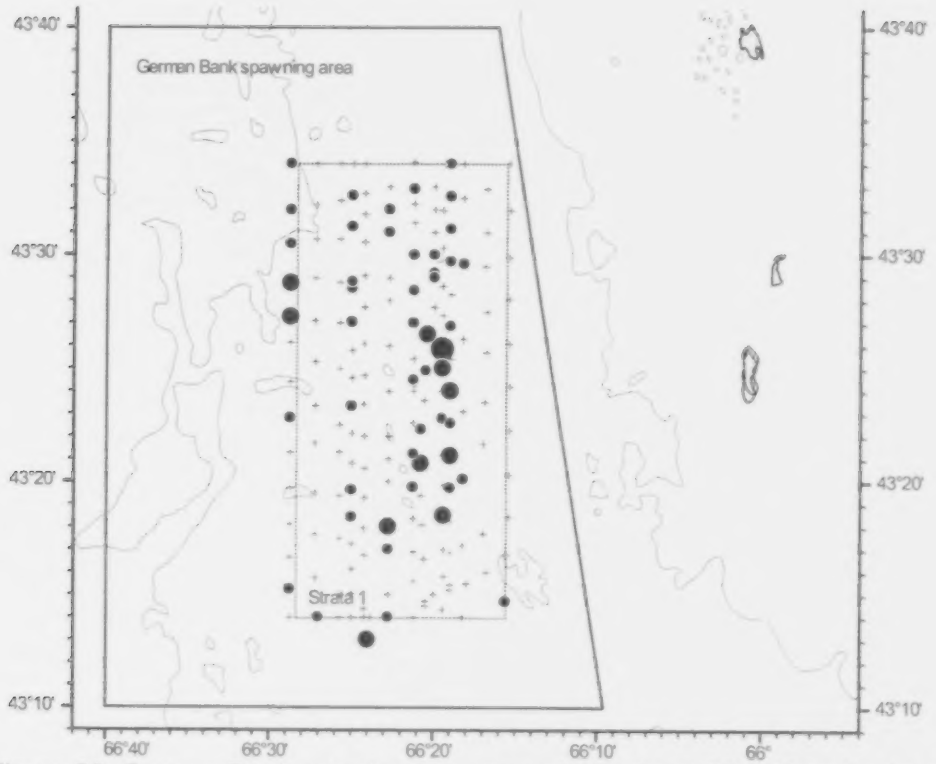

Figure 26. German Bank mapping survey results for Sept. 30, 2004 with dot size corresponding to density of fish sightings encountered. Overall spawning area (solid line) and standard survey area Strata 1 (dashed line) are also shown.

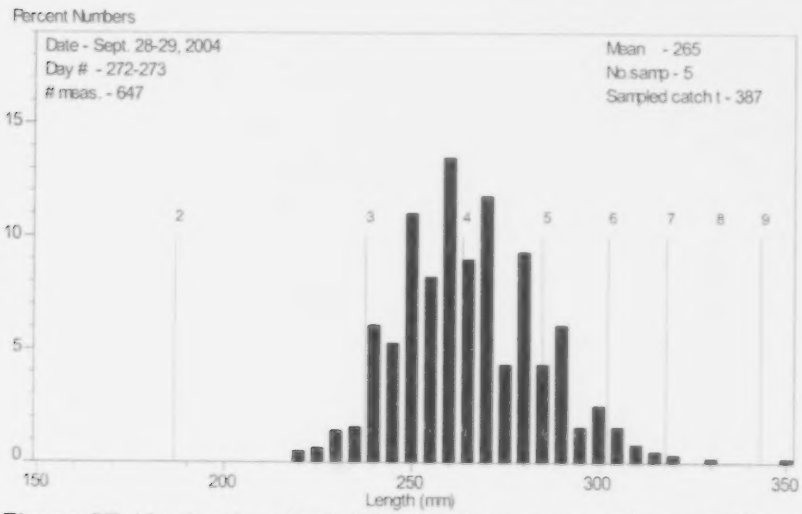

Figure 27. Herring length distribution from purse seine samples collected from German Bank landings on Sept. 28-29, 2004 (with mean Sept. ages from 1994-2003 historical samples).

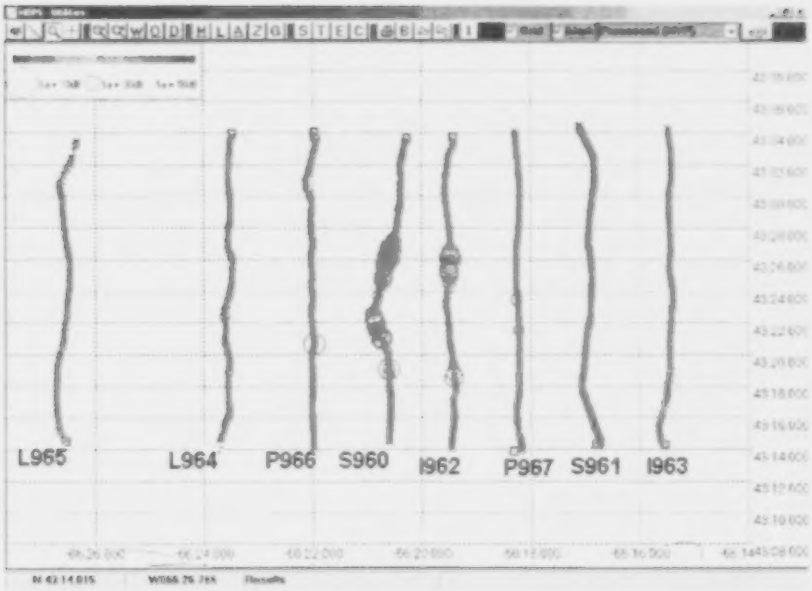

Figure 28. Acoustic transects for Sept. 30, 2004 German Bank survey showing location and density of herring observations from sounder recordings.

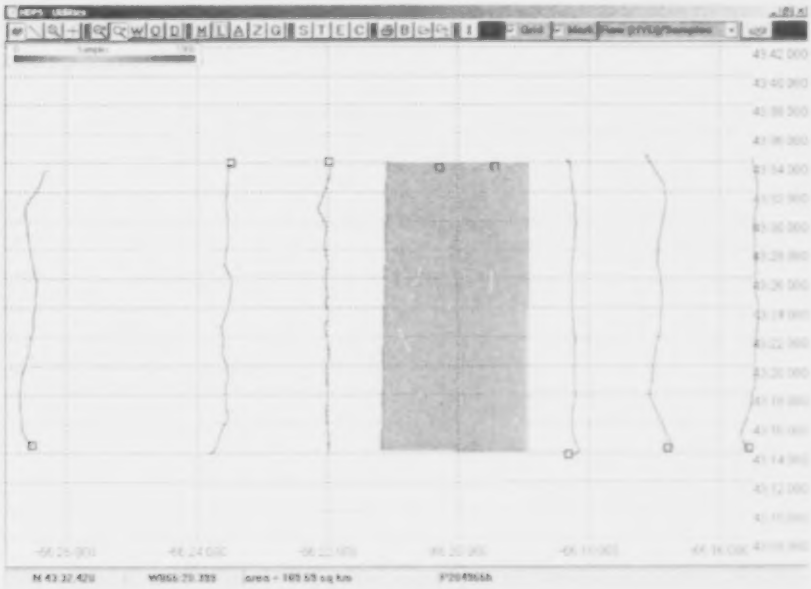

Figure 29. Acoustic transects for Sept. 30, 2004 German Bank survey with estimation of area of 110 km^2 for the two main transects containing fish.

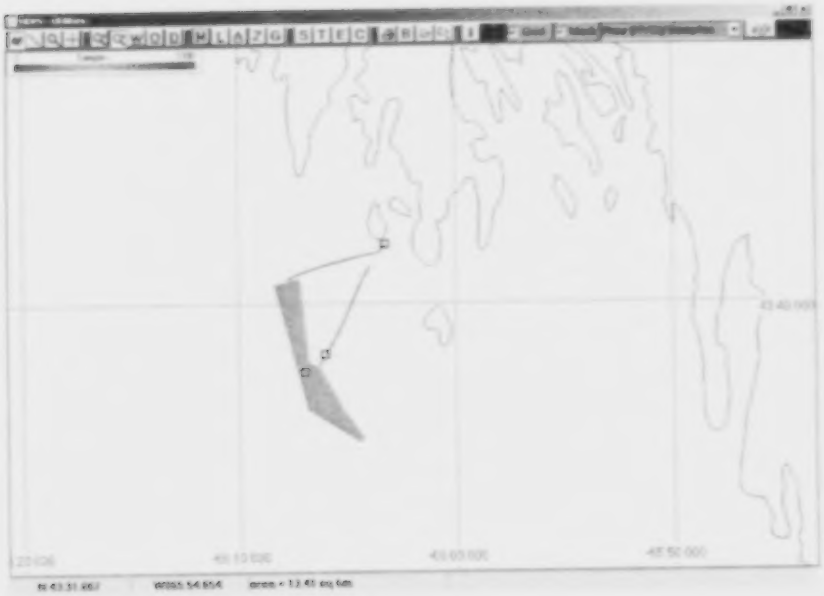

Figure 30. *Jessica & Trevor* survey near Spectacle Buoy on Aug. 22 (outside the normal spring season and early for the fall spawning period). No targets (fish) were observed and so no further analysis was done. There was also a lack of useable transects in the survey track.

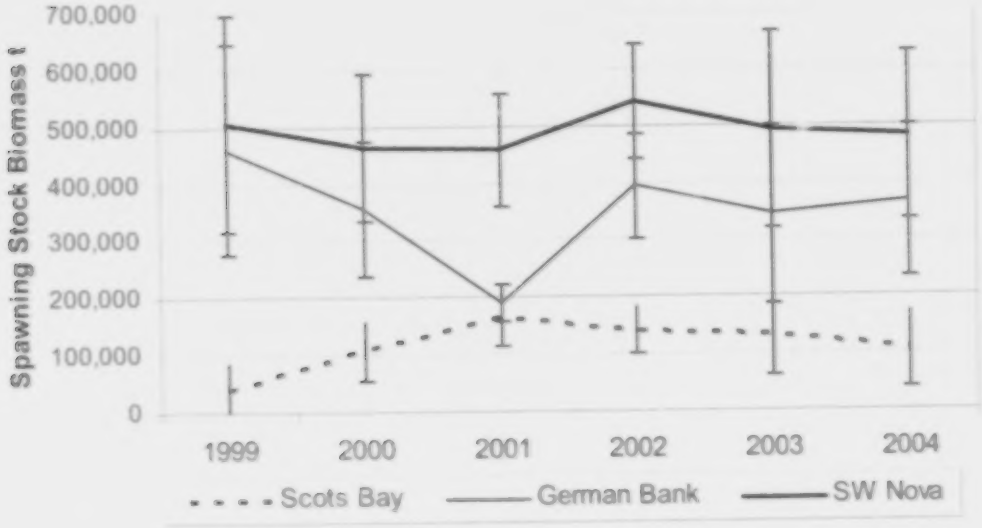

Figure 31. Trends in spawning stock biomass from acoustic surveys in Scots Bay, German Bank and the combined southwest Nova Scotia areas with 95% confidence intervals (equivalent to 2 times SE).

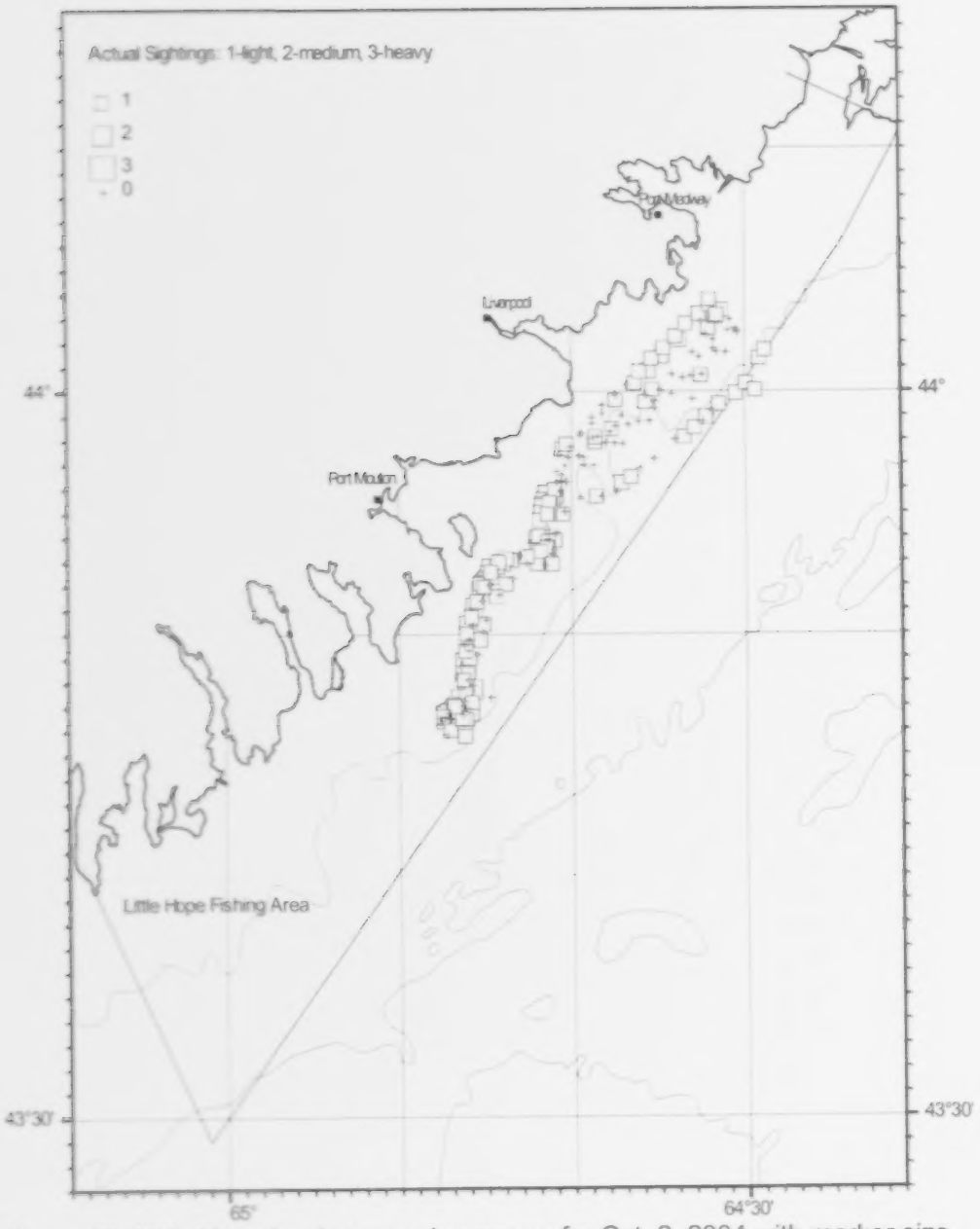

Figure 32. Little Hope herring mapping survey for Oct. 2, 2004 with marker size corresponding to density of fish sightings encountered. The overall defined fishing area is also shown (solid line).

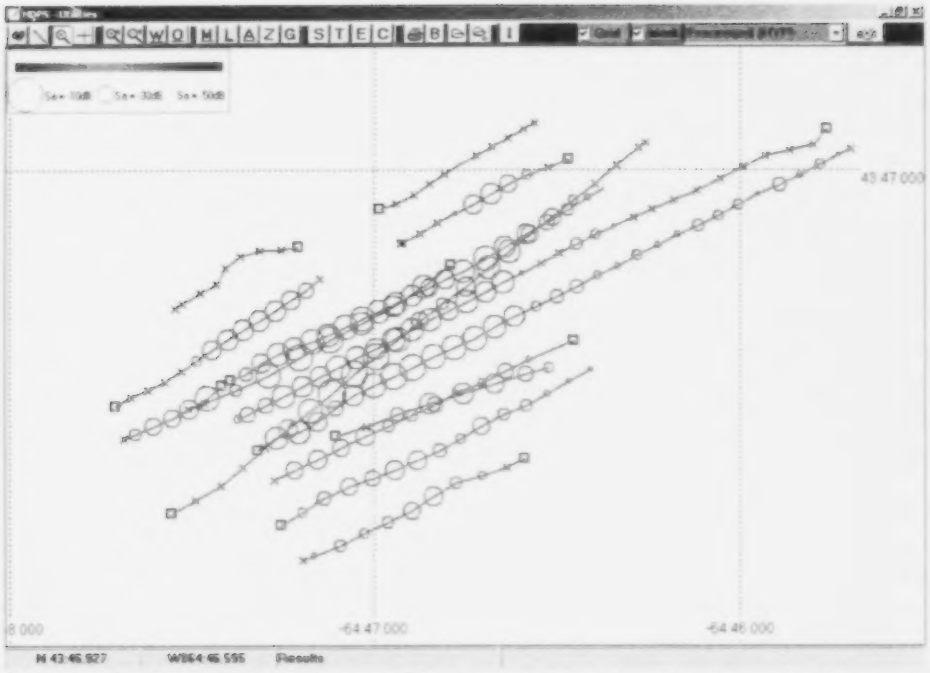

Figure 33. Little Hope Oct. 2, 2004 survey transects showing edited sounder data and location of herring along selected transects/lines in main area of fish located.

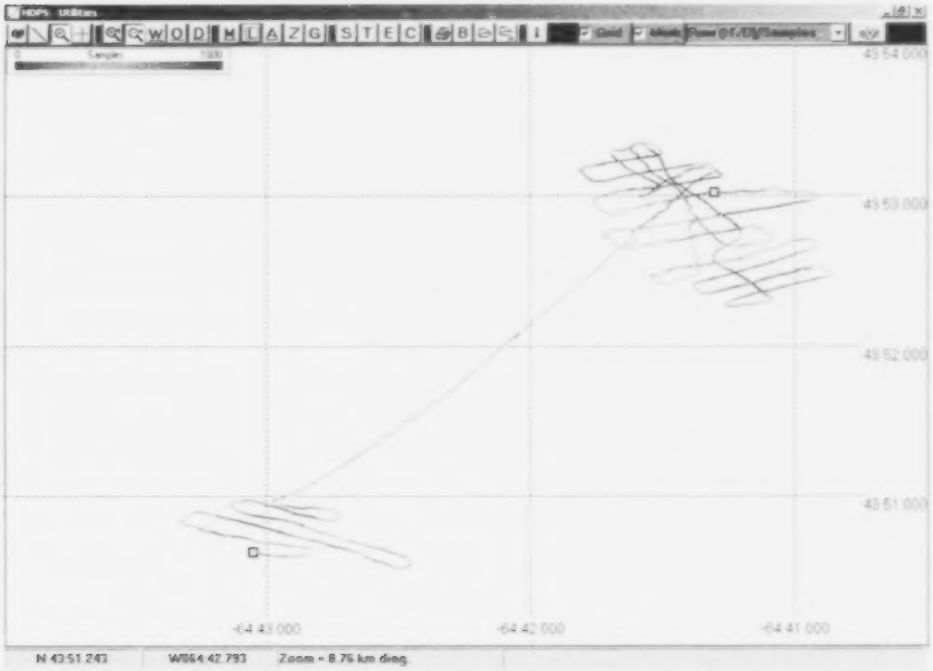

Figure 34. Acoustic survey tracks in the Little Hope area by *Jessica Trevor* on Oct. 13, 2004.

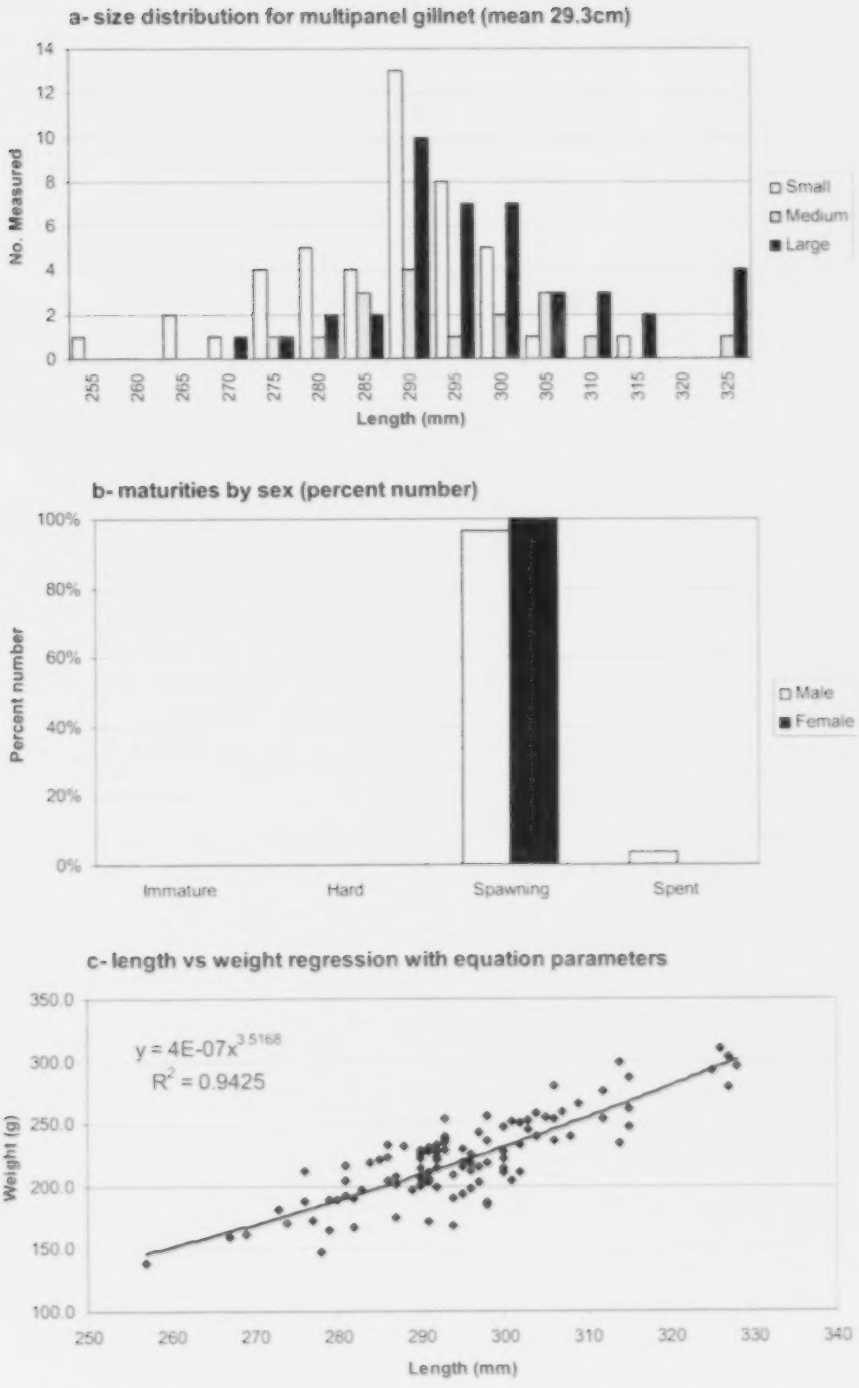

Figure 35. Sampling data for Eastern Shore multipanel gillnet on Sept. 28, 2004 with a) size distribution b) maturity proportions by sex and c) regression of length vs weight.

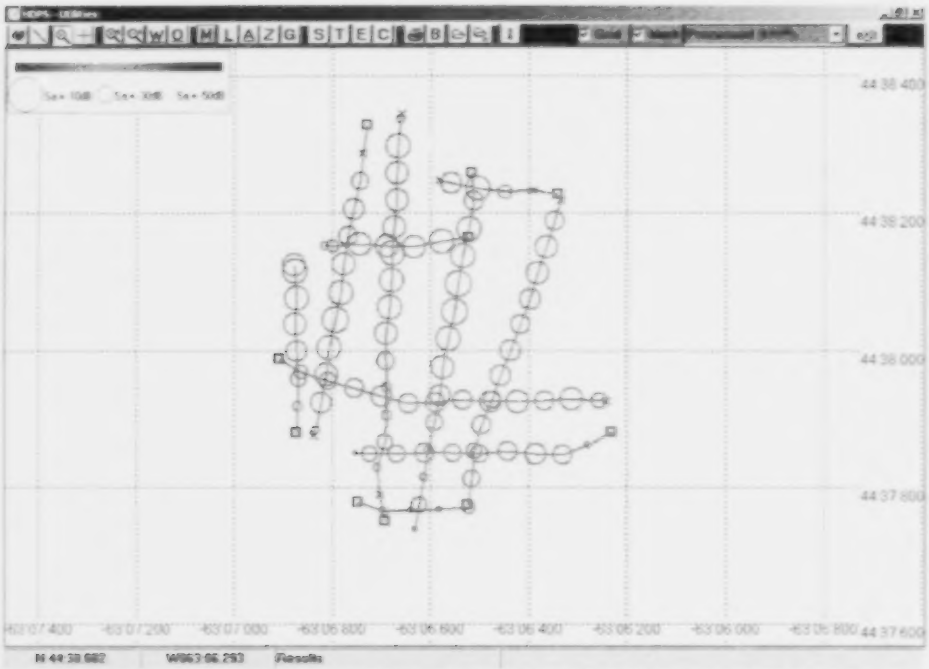

Figure 36. Eastern Shore survey on Sept 24, 2004 showing the survey lines completed with expanding circle sizes representing herring backscatter.

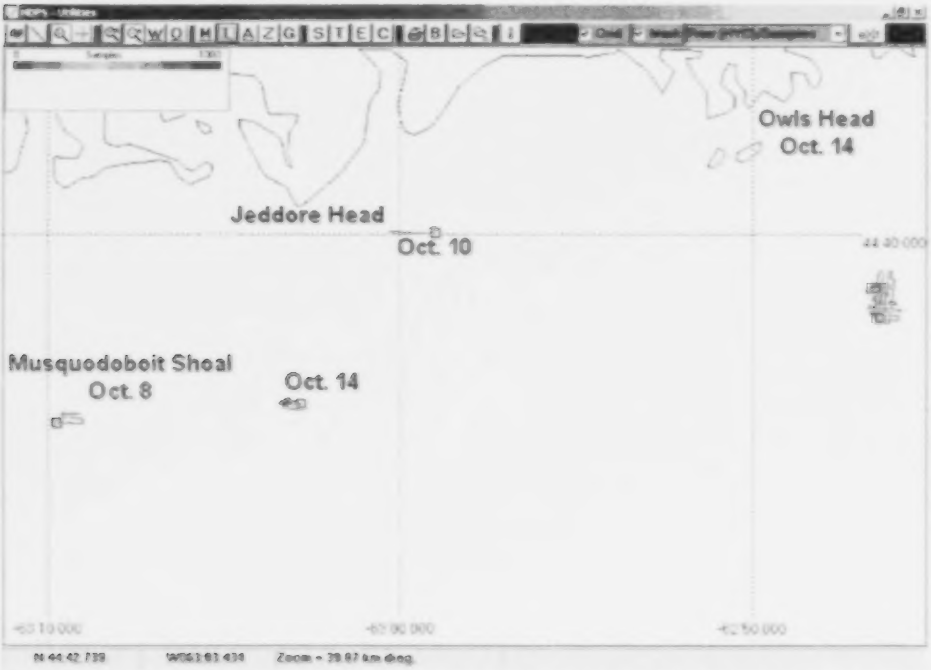

Figure 37. Eastern Shore surveys from Oct. 8 - 14, 2004 showing the areas of acoustic coverage and place name locations.

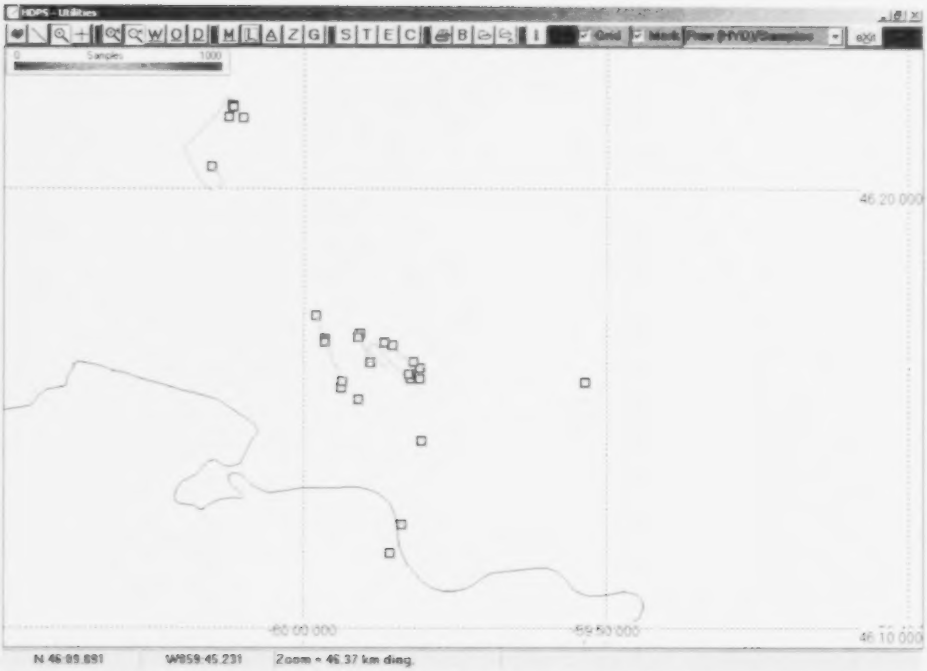

Figure 38. Survey coverage using an acoustic recorder from September 9-12, 2004 on the Glace Bay area herring spawning grounds.

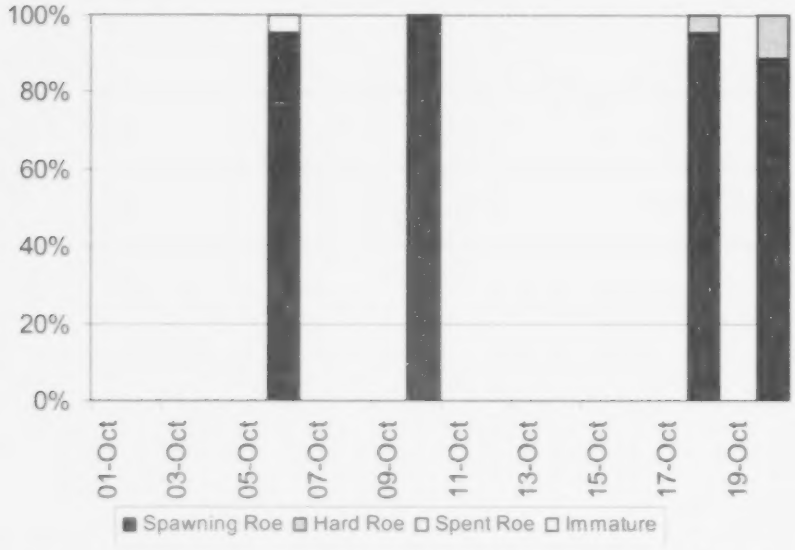

Figure 39. Daily herring female gonad maturity samples (% female roe weight) from the Glace Bay fishery collected for SABS.

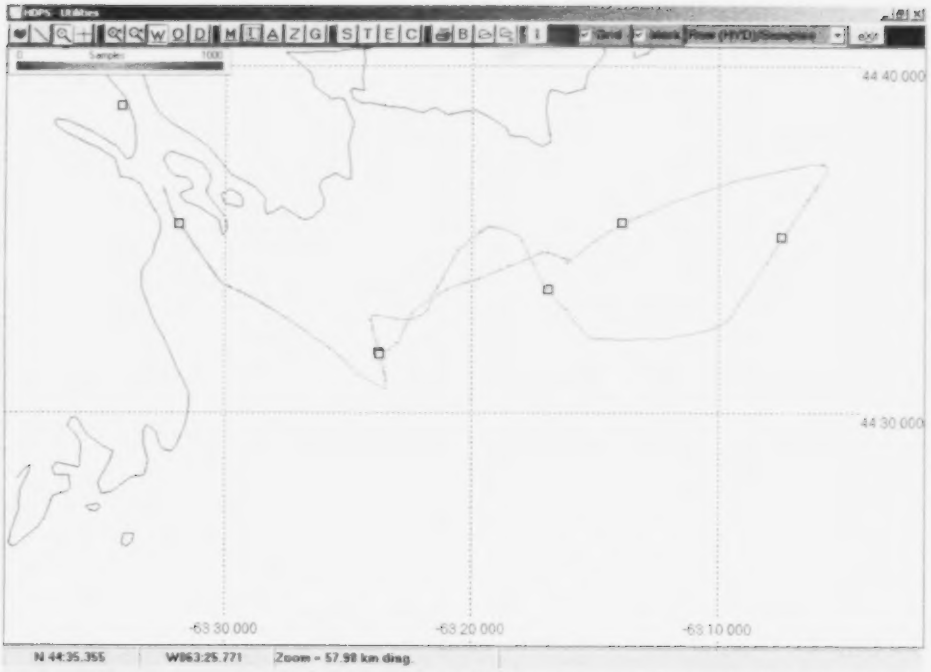

Figure 40. Survey track on Jan. 10, 2005 by *Leroy & Barry* in the approaches to Halifax Harbour, N.S. No aggregations of fish were encountered and no further analysis was done.